

TABLE 6-5. RESULTS OF ELUTRIATE BIOASSAY TESTING WITH *Cyprinodon variegatus* (SHEEPSHEAD MINNOW) ON SAMPLES FROM THE NAVAL STATION PENSACOLA TURNING BASIN, PENSACOLA, FLORIDA

Test Elutriate	96-Hour Survival				96-Hour LC ₅₀ (% elutriate)
	<u>Lab Control</u>	Percent Elutriate			
		10 %	50 %	100%	
PNSREF02	100	100	98	100	>100
PNS02-01	98	98	98	100	>100
PNS02-02	98	100	100	100	>100
PNS02-03	100	100	98	96	>100
PNS02-04	100	100	98	100	>100
PNS02-05	100	100	100	100	>100

TABLE 6-6. WATER QUALITY PARAMETERS MEASURED DURING 10-DAY WHOLE SEDIMENT TOXICITY TESTING WITH *Neanthes arenaceodentata* FOR NAVAL STATION PENSACOLA TURNING BASIN, PENSACOLA, FLORIDA

Test Elutriate	Mean (\pm Standard Deviation)			
	Temperature (°C)	pH	Dissolved Oxygen (mg/L)	Salinity (ppt)
CONTROL	20.4-21.4 ^(a) 21.0 (\pm 0.4)	7.6-8.1 7.9 (\pm 0.1)	4.9-6.1 5.6 (\pm 0.4)	28.2-29.6 29.1 (\pm 0.5)
PNSREF02	20.6-21.5 ^(a) 21.0 (\pm 0.3)	7.9-8.3 8.1 (\pm 0.1)	5.2-6.0 5.6 (\pm 0.3)	28.2-30.6 29.8 (\pm 0.7)
PNS02-01	20.6-21.5 ^(a) 21.1 (\pm 0.3)	8.1-8.4 8.3 (\pm 0.1)	5.1-6.7 5.8 (\pm 0.5)	28.9-30.7 30.0 (\pm 0.6)
PNS02-02	20.6-21.6 ^(a) 21.1 (\pm 0.3)	7.9-8.3 8.1 (\pm 0.1)	4.7-6.3 5.5 (\pm 0.4)	28.6-31.3 30.0 (\pm 0.7)
PNS02-03	20.5-21.7 ^(a) 21.2 (\pm 0.4)	7.9-8.3 8.1 (\pm 0.1)	4.4-5.7 5.1 (\pm 0.4)	29.0-31.0 29.8 (\pm 0.5)
PNS02-04	20.5-21.7 ^(a) 21.2 (\pm 0.3)	7.9-8.2 8.1 (\pm 0.1)	4.3-5.2 4.8 (\pm 0.3)	28.6-30.2 29.5 (\pm 0.5)
PNS02-05	20.5-21.6 ^(a) 21.1 (\pm 0.4)	7.9-8.3 8.1 (\pm 0.1)	5.0-6.2 5.7 (\pm 0.4)	29.0-30.5 29.8 (\pm 0.5)

(a) Temperature was greater than the target range of $20\pm1^{\circ}\text{C}$ on several days.

TABLE 6-7. WATER QUALITY PARAMETERS MEASURED DURING 10-DAY WHOLE SEDIMENT TOXICITY TESTING WITH *Leptocheirus plumulosus* FOR NAVAL STATION PENSACOLA TURNING BASIN, PENSACOLA, FLORIDA

Test Elutriate	Mean (\pm Standard Deviation)			
	Temperature (°C)	pH	Dissolved Oxygen (mg/L)	Salinity (ppt)
CONTROL	21.0-22.1 ^(a)	7.5-8.2	4.3-6.7	20.0-22.0
	21.7 (\pm 0.3)	7.8 (\pm 0.2)	5.6 (\pm 0.6)	21.0 (\pm 0.6)
PNSREF02	20.8-21.8 ^(a)	7.8-8.3	4.0-6.9	20.3-23.5 ^(b)
	21.4 (\pm 0.4)	8.0 (\pm 0.1)	5.6 (\pm 0.9)	21.9 (\pm 1.1)
PNS02-01	21.0-22.1 ^(a)	8.0-8.3	4.3-6.9	19.7-23.1 ^(b)
	21.6 (\pm 0.4)	8.2 (\pm 0.1)	5.6 (\pm 0.9)	21.6 (\pm 1.1)
PNS02-02	20.8-21.9 ^(a)	7.8-8.3	4.1-6.9	19.8-24.1 ^(b)
	21.5 (\pm 0.3)	8.0 (\pm 0.2)	5.8 (\pm 0.8)	22.1 (\pm 1.3)
PNS02-03	21.0-21.9 ^(a)	7.8-8.3	4.6-7.3	19.8-23.5 ^(b)
	21.4 (\pm 0.3)	8.0 (\pm 0.1)	5.8 (\pm 0.8)	22.1 (\pm 1.2)
PNS02-04	21.0-21.9 ^(a)	7.8-8.2	4.1-7.2	18.6-22.5 ^(b)
	21.5 (\pm 0.3)	8.1 (\pm 0.1)	5.7 (\pm 0.9)	21.1 (\pm 1.2)
PNS02-05	21.0-21.8 ^(a)	7.8-8.3	4.5-7.1	19.8-23.1 ^(b)
	21.4 (\pm 0.3)	8.0 (\pm 0.1)	5.9 (\pm 0.8)	21.5 (\pm 1.0)

- (a) Temperature was greater than the target range of $20\pm 1^\circ\text{C}$ on several days.
(b) Salinity was greater than the target range of 20 ± 2 ppt on several days.

TABLE 6-8. RESULTS OF 10-DAY WHOLE SEDIMENT TOXICITY TESTING WITH *Neanthes arenaceodentata* FOR NAVAL STATION PENSACOLA TURNING BASIN, PENSACOLA, FLORIDA

Test Sediment	No. Alive/ No. Exposed*	28-Day Percent Survival (percent)
CONTROL	24 / 25	96
PNSREF02	24 / 25	96
PNS02-01	20 / 25	80 ^a
PNS02-02	22 / 25	88
PNS02-03	18 / 20 ^b	90
PNS02-04	24 / 25	96
PNS02-05	24 / 25	96

Total for 5 replicates of 5 animals for all test sediments

- (a) Mean survival was significantly ($p=0.05$) lower than the reference sediment (PNSREF02).
(b) One of the replicates was excluded from statistical analyses as an anomalous value.

TABLE 6-9. RESULTS OF 10-DAY WHOLE SEDIMENT TOXICITY TESTING WITH *Leptocheirus plumulosus* FOR NAVAL STATION PENSACOLA TURNING BASIN, PENSACOLA, FLORIDA

Test Sediment	No. Alive/ No. Exposed*	28-Day Percent Survival (percent)
CONTROL	95 / 100	95
PNSREF02	84 / 100	84
PNS02-01	64 / 100	64 ^a
PNS02-02	79 / 100	79
PNS02-03	79 / 100	79
PNS02-04	49 / 100	49 ^a
PNS02-05	82 / 100	82

Total for 5 replicates of 20 animals for all test sediments

(a) Mean survival was significantly ($p=0.05$) lower than the reference sediment (PNSREF02).

TABLE 6-10. RESULTS OF REFERENCE TOXICANT TESTING ON ACQUIRED LOTS OF TEST ORGANISMS

<u>Test Species</u>	<u>Organism Lot Number</u>	<u>Reference Toxicant</u>	<u>Test Endpoint</u>	<u>Acceptable Control Chart Limits</u>
<i>Arbacia punctulata</i>	AP-011	Copper chloride (CuCl ₂)	48-Hour EC50: 74.6 µg/L Cu	5.4-93.2 µg/L Cu
<i>Americamysis bahia</i>	MB-481	Potassium chloride (KCl)	48-Hour LC50: 695 mg/L KCl	559-730 mg/L KCl
<i>Cyprinodon variegatus</i>	CV-367	Potassium chloride (KCl)	48-Hour LC50: 1,414 mg/L KCl	1,142-1,634 mg/L KCl
<i>Neanthes arenaceodentata</i>	NA-011	Cadmium chloride (CdCl ₂)	96-hour LC50: 5.7 mg/L Cd	0-14.1 mg/L Cd
<i>Leptocheirus plumulosus</i>	LP-020	Cadmium chloride (CdCl ₂)	48-hour LC50: 8.0 mg/L Cd	0-15.9 mg/L Cd

7. BIOACCUMULATION STUDIES

Sediments from Naval Station Pensacola turning basin were evaluated in 28-day bioaccumulation studies with *Nereis virens* (sand worm) and *Macoma nasuta* (blunt-nose clam). The studies measured survival of the test organisms and the potential for bioaccumulation of contaminants in organism tissue as a result of exposure to Naval Station Pensacola sediment samples.

7.1 MATERIALS AND METHODS

Methodology for the bioaccumulation studies followed guidance in USEPA/USACE (1998), USACE-SAD/USEPA Region IV (1993), and USEPA/USACE (1991). Bioaccumulation testing protocols are described in the QAPP for the ecotoxicological testing program (EA 2002c). Original data sheets and records for the bioaccumulation exposures are archived at EA's Baltimore Office in Sparks, Maryland. These data will be retained for a period of 5 years.

7.1.1 Test Setup and Procedures

Bioaccumulation testing was conducted with the sand worm (*N. virens*) and the blunt-nose clam (*M. nasuta*). The adult worms (lot NV-026) and the adult clams (lot MA-019) were obtained from Aquatic Research Organisms (Hampton, New Hampshire) on 28 March 2002.

The sediment samples and overlying water were added to the test chambers the day prior to test initiation. The overlying water was artificial seawater (Forty Fathoms sea salts). Natural sediments from the organism collection sites served as laboratory controls in the bioaccumulation testing. The bioaccumulation tests were 28 days in duration and were conducted as static, renewal assays. The overlying water was replaced three times a week by siphoning approximately 80 percent of the overlying water from the aquaria and replacing with new overlying water, taking care not to disturb the sediment surface.

The bioaccumulation tests were conducted in 10-gallon aquaria with approximately 6 L of sediment and 19 L of overlying water per aquarium. There were five replicates per sediment sample and three replicates per control sediment. Based on the analytical tissue biomass requirements, 20 organisms were randomly introduced into each replicate chamber for the *N. virens* testing, while the *M. nasuta* testing utilized 50 organisms per chamber.

During the 28-day exposure period, the test chambers were maintained at $20\pm 1^{\circ}\text{C}$ (*N. virens*) and $12\pm 1^{\circ}\text{C}$ (*M. nasuta*) with a 16-hour light/8-hour dark photoperiod. Gentle aeration was provided to each aquarium throughout the test period. Observations of mortality and abnormal organism behavior were recorded daily, and dead organisms were removed as observed from the test chambers. Measurements of temperature, pH, dissolved oxygen, and salinity of the overlying water were recorded daily on one replicate of each sample and control. The water quality measurements are summarized in Table 7-1 (*N. virens*) and Table 7-2 (*M. nasuta*). The organisms were not fed during the exposure period.

The bioaccumulation tests were initiated on 28 March and completed on 25 April 2002. After 28 days of exposure, the organisms were recovered from the sediments and placed into clean artificial seawater for 24 hours to purge their digestive tracts. After the depuration period, the organism tissues were collected and submitted for chemical analyses. Copies of the original data sheets from the *N. virens* and *M. nasuta* testing are included in Attachment F. The survival results are presented in Table 7-3 (*N. virens*) and Table 7-4 (*M. nasuta*).

7.1.2 Reference Toxicant Testing

In conformance with EA's QA/QC program requirements, reference toxicant testing was performed on the acquired lots of *N. virens* and *M. nasuta* utilized in the testing program. The reference toxicant tests consisted of a graded concentration series of a specific toxicant in water only tests, with no sediment present in the test chambers.

The reference toxicant for the bioaccumulation species, *N. virens* and *M. nasuta*, was sodium dodecyl sulfate (SDS). The results of the reference toxicant tests (Table 7-5) were compared to established laboratory control chart limits.

7.1.3 Tissue Preparation and Homogenization

After 28 days of exposure, surviving organisms were recovered and placed in holding tanks containing 20 ppt artificial sea water and no sediment to purge their digestive tracts. The organisms were not fed during this period. At the end of the 24-hour purging period, the shells of the clams were rinsed with de-ionized (DI) water, the clams were shucked, and the soft tissues and liquids inside the shell were placed into pre-cleaned glass jars. Worms were rinsed with DI water to remove the external salts (originating from the purge chambers) and were placed directly into pre-cleaned glass jars. Tissues for each replicate were placed into separate jars, labeled, and frozen until delivered to the analytical laboratory. Required containers, preservation techniques, and holding time requirements for tissue samples are provided in Table 7-6.

In addition to test tissues, pre-test tissue and tissue from control organisms were also submitted for analysis. Pre-test tissue represents organism tissue upon receipt at the ecotoxicology laboratory (prior to test initiation). These tissues originate from organisms that are sacrificed from each shipment and subsequently frozen. These organisms are not exposed to test sediments, but contaminants in their tissues would represent baseline contaminants that accumulated in their natural environment. Control tissue originates from organisms exposed to natural sediment (that they were shipped in) after a 28-day exposure period. These organisms are exposed to the same laboratory environment as the test sediments.

Tissues were held frozen until determination of project target analytes and until the project delivery order was modified to include analysis of additional target analytes. Tissues for each replicate were then separately thawed, homogenized, and weighed to the nearest gram. Aliquots from each replicate were removed for analysis of target fractions. Prior to analytical testing, determination of percent moisture was conducted by EA's Ecotoxicology Laboratory.

7.1.4 Analytical Methods and Reporting Limits

Tissue samples were analyzed for the following analyte fractions: metals, PAHs, PCB congeners, chlorinated pesticides, lipids, and moisture content. Not all the analyte fractions were analyzed for every sampling location, as shown in the following table. Target fractions were selected based on the results of the sediment analyses, TBP calculations, and consultation with USACE–Mobile District.

	PNSREF02 (Reference)	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
Metals	X	X	X	X	X	X
Chlorinated Pesticides	X	X				
PCB Congeners	X	X	X			
PAHs	X	X	X			
Lipids	X	X	X	X	X	X

The project-specific analytical methods for tissue analyses are provided in Table 3-1. Reporting limits for tissue analyses are provided in Table 3-4. With the exception of the metals, percent moisture, and lipid determinations, Gel Permeation Chromatography (GPC) clean-up was conducted after the extraction process to reduce lipids and other analytical interferences associated with the tissue matrix during the analyses of organic compounds.

7.1.5 Data Analysis and Statistics

The effects of the Naval Station Pensacola sediments on test organism survival and chemical accumulation in tissues were evaluated by comparison to tests with the Pensacola Bay reference sediment. Statistical analyses of survival data and tissue chemistry data were performed according to procedures outlined in the *Inland Testing Manual* (ITM) (USEPA/USACE 1998) and the *Ocean Testing Manual* (OTM) (USEPA/USACE 1991). In addition, uptake ratios (URs) were calculated to assist with the evaluation of the statistical results.

Survival Data

Overall percent survival of test organisms in the five replicate tests for each sediment sample was calculated to determine whether organism exposure to the Naval Station Pensacola turning basin sediments resulted in reduced survival of the test organisms as compared to the reference sediment. If survival in a test sample was at least 10 percent lower than the reference, then a t-Test or Wilcoxon's Rank-Sum Test (depending on data characteristics) was performed to compare the single test sample to the reference.

Determination of Total PCBs and Total PAHs in Tissue

For each sample, total PCB concentrations were determined by summing the concentrations of the 18 summation congeners (as specified in Table 9-3 of the ITM) and multiplying the total by a factor of 2. Multiplying by a factor of 2 estimated the total PCB concentration and accounted for additional congeners that were not tested as part of this program. In the summation calculation, the reporting limit (RL) was substituted for constituents that were not detected (ND=RL). These determinations were based upon testing of specific congeners recommended in the ITM and upon the National Oceanic and Atmospheric Administration (NOAA 1993) approach for total PCB determinations.

Total PAHs were determined by summing the concentrations of PAHs in each sample, where non-detects = reporting limit (ND=RL). The substitution of one-half the reporting limit (ND=RL) provides a conservative approach to calculating and evaluating the data. However, in cases where few PAHs are detected, the reporting limit drives the total value and overestimates the actual expected concentration. This overestimation is important to consider when comparing total calculated values to criteria or screening values.

Mean total PAH concentrations that were used in the means comparison statistics were determined by averaging the total that was calculated for each individual replicate. In the PAH tables, note that the average of the sums does not equal the sum of the average concentrations for each congener or analyte for calculations using ND=RL.

Tissue Chemical Residue Data

Before performing the statistical protocols to evaluate whether organisms exposed to Naval Station Pensacola sediments accumulated higher concentrations of analytes in tissue than those exposed to reference site sediments, several steps were taken to prepare the tissue data for evaluation. These steps were:

- Treatment of data reported below the reporting limit; and
- Characterizing the distribution (normal, lognormal, nonparametric) and variance of tissue-residue data.

Each of these steps is described below. The bioaccumulation data analysis process is illustrated in Figure 7-1.

Treatment of Tissue-Residues Below the Analytical Reporting Limit

When the tissue concentration of an analyte is not greater than a value that reflects a reliable quantity, the analytical laboratory either reports the data as an estimated concentration (qualified by "J") or as not detected (ND or U). Where data were reported as estimated, the reported concentration was assumed to be a true value in the statistical analyses. In cases where a chemical was detected in the laboratory blank (qualified by a "B"), the reported concentration

was also assumed to be a true value in the statistical analyses; however, mean concentrations calculated using “B” qualified data are flagged with a “B” in the summary tables.

Most statistical methods in the ITM (USEPA/USACE 1998) cannot be directly applied in cases where some contaminant concentrations are reported as less than the analytical detection limit (DL). Data that were reported as not detected (censored) were treated in accordance with guidelines presented by Clark (1995) for small samples. The actual concentrations of these data are unknown and are presumed to fall between zero and the detection limit (DL). Clark (1995) examined various methods for handling small data sets that include non-detects, and found that, in most cases, substitution of DL/2 was an appropriate conservative approach. In general, statistical power (i.e., the probability of correctly rejecting the null hypothesis) will decline as the amount of censoring increases. In cases where the data are more than 60 to 80 percent non-detects, it is unlikely that any censoring method will result in acceptable statistical power. Following these guidelines, tissue-residue data were censored to replace the non-detects with one-half the reporting limit. Where all (100 percent) bioaccumulation test replicates were reported as non-detected, the analyte was assumed to be absent from the tissue (ND=0).

Tissue Contaminant Concentrations Compared to Reference

A flow diagram depicting the decision tree for statistical comparisons to the reference site is presented in Figure 7-1. Statistical analyses were completed using programs from SAS[®] Version 8. Tissue residues of organisms exposed to the channel sediments were compared to tissue residues from organisms exposed to reference sediments. This was accomplished by using analysis of variance (ANOVA) followed by Dunnett’s test for multiple comparisons. In cases where the assumptions of normality and homogeneity of variances could not be verified, the nonparametric Wilcoxon Rank Sum test was used. Prior to the analysis, data were censored to replace non-detects with one-half the reporting limit.

Characterization of Data Distribution and Variance

To determine the appropriate statistical test protocol by which to compare Naval Station Pensacola tissue concentrations to reference site tissue concentrations, the data for each case was characterized with respect to distribution and variance.

Although ANOVA is fairly robust to deviations from distribution assumptions, the validity of the assumptions of normality and homogeneity of variances was tested. Tests for normality for each analyte were conducted by combining tissue-residue concentrations from all sites and computing the Shapiro Wilk’s W statistic for the residuals as described in Conover (1980). Following USEPA 1998 guidance for $N > 20$, a normal distribution was rejected if $W < W_{crit}$ at the 1 percent confidence level ($\alpha = 0.01$). Levene’s test was used to determine if variances among sites were significantly different ($\alpha = 0.1$) (USEPA 1998 for $n = 2$ to 9). If assumptions of normality of homogeneity of variance were not met, then data were log-transformed. If the log-transform failed to stabilize the distribution or variance, then nonparametric tests were used for means comparisons.

Uptake Ratios

To evaluate the magnitude of chemical uptake and to assist with the evaluation of the statistically significant tissue-residue results, an uptake ratio (UR) was calculated to assess the magnitude of contaminant uptake by organisms during the 28-day period. The 28-day uptake ratio was derived as the ratio of the day 28 mean tissue-residue concentration to the day 0 (PRETEST tissue) mean tissue-residue concentrations for each chemical analyte:

$$UR = \frac{\bar{X}_{t=28}}{\bar{X}_{t=0}}$$

where:

UR = uptake ratio
 $\bar{X}_{t=0}$ = day 0 (PRETEST) mean tissue-residue concentration
 $\bar{X}_{t=28}$ = day 28 mean tissue-residue concentration

Tissue Contaminant Concentrations Compared to USEPA Tolerance/Guidance Levels

For constituents with USEPA Tolerance/Guidance Levels (USFDA 1998), the criterion was compared to the one-tailed 95 percent upper confidence level of the mean (UCLM) tissue-residue concentration at each site. If the UCLM was below the action level (indicating a 95 percent probability that the population mean tissue-residue concentration for the site is below the action level), it was concluded that the action level was not exceeded. For normally distributed data, the UCLM was calculated as:

$$UCLM = \bar{x} + t_{[0.95,df]} \sqrt{s^2 / n}$$

where:

\bar{x} = sample mean
 s^2 = variance
 n = number of sample replicates
 $t_{[0.95,df]}$ = one-tailed Student's t statistic for $\alpha = 0.95$ and df degrees of freedom

For lognormally distributed data, the UCLM was calculated as:

$$UCLM = \exp(\bar{y} + t_{[0.95,df]} \sqrt{s_y^2 / n})$$

Sokal and Rohlf (1981),

where:

\bar{y} = sample mean of log-transformed data
 s_y^2 = variance of log-transformed data
 n = number of sample replicates

$t_{[0.95,df]}$ = one-tailed Student's t statistic for $\alpha = 0.95$ and df degrees of freedom

If variances were not statistically different (Levene's test), the mean square error (MSE) was used as the estimator for the variance. The t -statistic was then evaluated for $df = N - k$ degrees of freedom, where N is the total number of observations ($\sum_{i=1}^k n_i$) and k is the number of sites. If variances were unequal, then the UCLM was computed using the sample variance and $t_{[0.95,df]}$ was evaluated for $df = n - 1$ degrees of freedom.

7.2 BIOACCUMULATION RESULTS

7.2.1 Survival

Nereis virens

Results from the bioaccumulation tests with *N. virens* are provided in Table 7-3. After 28 days of exposure, none of the test sediments had significantly ($p=0.05$) lower survival than the reference sediment, indicating that the sediments were did not adversely affect survival during the exposure period of *N. virens*. Survival in the five test sediments ranged from 98 to 100 percent survival. The reference sediment and the control sediment had 100 percent survival.

Macoma nasuta

Results from the bioaccumulation tests with *M. nasuta* are provided in Table 7-4. After 28 days of exposure, none of the test sediments had significantly ($p=0.05$) lower survival than the reference sediment, indicating that the sediments were did not adversely affect survival during the exposure period of *M. nasuta*. The reference sediment had 98 percent survival, and the control sediment had 99 percent survival. The five test sediments had survival that ranged from 93 to 98 percent.

7.2.2 Tissue Contaminant Analysis

Results of the tissue chemistry analyses are presented in the following sections. The mean analyte concentration for five replicate analyses was used for comparisons. The raw data for each tissue replicate and the analytical detection limits are provided in Attachment G. Analytical results are reported on a wet weight basis. Lipid content is reported as a percent of total body weight.

Required holding times, preservation techniques, and sample containers for tissue samples are provided in Table 7-6. Data qualifiers for the organic and inorganic data are provided in Tables 4-2 and 4-3, respectively. Analytical narratives, which include a synopsis of laboratory QA/QC results for Laboratory Control Samples and Matrix Spike/Matrix Spike Duplicate Recoveries, are provided in Attachment G. The analytical laboratory will retain and archive the results of these analyses for seven years from the date of issuance of the final results.

7.2.2.1 PAHs

Nereis virens

Table 7-7 presents the mean concentrations of PAHs in worm tissues exposed to Naval Station Pensacola turning basin sediments and highlights concentrations that are statistically higher than concentrations reported for worm tissues exposed to the reference sediment. Based on the results of the sediment analyses, PAH concentrations were determined in the tissue samples for PNS02-01, PNS02-02, and PNSREF02 only. Uptake ratios for PAHs in worm tissue are provided in Table 7-8.

None of the PAHs detected in the Naval Station Pensacola turning basin worm tissue had mean concentrations that statistically exceeded the Pensacola Bay reference site tissue concentrations.

Macoma nasuta

Table 7-9 presents the mean concentrations of PAHs in clam tissues exposed to Naval Station Pensacola turning basin sediments and highlights concentrations that statistically exceeded concentrations reported for clam tissues exposed to the reference sediment. Based on the results of the sediment analyses, PAH concentrations were determined in the tissue samples for PNS02-01, PNS02-02, and PNSREF02 only. Uptake ratios for PAHs in clam tissue are provided in Table 7-10.

Mean concentrations of two PAHs – fluoranthene and pyrene - detected in worm tissue from PNS02-02 were statistically greater than concentrations detected in the Pensacola Bay reference tissue.

7.2.2.2 Metals

Nereis virens

Table 7-11 presents the mean concentrations of metals in worm tissues exposed Naval Station Pensacola turning basin sediments and highlights concentrations that are statistically higher than concentrations reported for worm tissues exposed to the reference sediment. Mean concentrations of metals statistically exceeded reference site concentrations in 4 of 90 cases (4 percent). Uptake ratios for metals in worm tissue are provided in Table 7-12.

Mean concentrations of arsenic at PNS02-05, copper at PNS02-01, and zinc at PNS02-03 and PNS02-04 statistically exceeded mean reference site concentrations in tissue samples from at least one Naval Station Pensacola location. Uptake ratios for each of the metals with mean tissue concentrations that exceeded the reference site tissue concentrations were either less than or slightly greater than 1 (Table 7-12). When the UR is less than 1, concentrations for the test tissues were actually lower than the concentrations reported in the pre-test tissue (non-exposed tissue). In such cases, it is possible that the significant exceedances represent either natural or analytical variability of concentrations within the tissue sample, rather than contaminant uptake from the sediment.

Macoma nasuta

Table 7-13 presents the mean concentrations of metals in clam tissues exposed to Naval Station Pensacola turning basin sediments and highlights concentrations that are statistically higher than concentrations reported for clam tissues exposed to the reference sediment. Uptake ratios for metals in clam tissue are provided in Table 7-14.

None of the metals detected in the Naval Station Pensacola turning basin clam tissue had mean concentrations that statistically exceeded the reference site tissue concentrations.

7.2.2.3 PCB Congeners

Nereis virens

Table 7-15 presents the mean concentrations of PCB congeners in worm tissues exposed Naval Station Pensacola turning basin sediments and highlights concentrations that are statistically higher than concentrations reported for worm tissues exposed to the reference sediment. Based on the results of the sediment analyses, PAH concentrations were determined in the tissue samples for PNS02-01, PNS02-02, and PNSREF02 only. Uptake ratios for PCB congeners in worm tissue are provided in Table 7-16.

None of the PCB congeners or total PCB concentrations detected in the Naval Station Pensacola turning basin worm tissue had mean concentrations that statistically exceeded the reference site tissue concentrations.

Macoma nasuta

Table 7-17 presents the mean concentrations of PCB congeners in clam tissues exposed to Naval Station Pensacola turning basin sediments and highlights concentrations that are statistically higher than concentrations reported for clam tissues exposed to the reference sediment. Based on the results of the sediment analyses, PCB concentrations were determined in the tissue samples for PNS02-01, PNS02-02, and PNSREF02 only. Uptake ratios for PCB congeners in clam tissue are provided in Table 7-18.

One PCB congener and the total PCB concentration (ND=RL) in the tissue residues from location PNS02-01 statistically exceeded the reference site tissue concentrations. However, uptake ratios for both were either less than or slightly greater than 1 (Table 7-18), indicating that concentrations for the test tissues were about the same as concentrations reported in the pre-test tissue (non-exposed tissue). Therefore, it is likely that the significant exceedances represent either natural or analytical variability of concentrations within the tissue sample, rather than contaminant uptake from the sediment.

7.2.2.4 Chlorinated Pesticides

Nereis virens

Table 7-19 presents the mean concentrations of chlorinated pesticides in worm tissues exposed to Naval Station Pensacola turning basin sediments and highlights concentrations that are statistically higher than concentrations reported for worm tissues exposed to the reference sediment. Based on the results of the sediment analyses, chlorinated pesticides concentrations were determined in the tissue samples for PNS02-01 and PNSREF02 only. Uptake ratios for chlorinated pesticides in worm tissue are provided in Table 7-20.

None of the chlorinated pesticide concentrations detected in the Naval Station Pensacola turning basin worm tissue had mean concentrations that statistically exceeded the reference site tissue concentrations.

Macoma nasuta

Table 7-21 presents the mean concentrations of chlorinated pesticides in clam tissues exposed to Naval Station Pensacola turning basin sediments and highlights concentrations that are statistically higher than concentrations reported for clam tissues exposed to the reference sediment. Based on the results of the sediment analyses, chlorinated pesticides concentrations were determined in the tissue samples from PNS02-01 and PNSREF02 only. Uptake ratios for chlorinated pesticides in worm tissue are provided in Table 7-22.

None of the chlorinated pesticide concentrations detected in the Naval Station Pensacola turning basin clam tissue had mean concentrations that statistically exceeded the reference site tissue concentrations.

7.2.2.5 Lipids

Mean lipid values for organisms exposed to Naval Station Pensacola turning basin sediments are presented in the table below. Mean lipid values ranged from 0.616 to 1.94 percent of total wet body weight for the worms and 0.502 to 1.04 percent of total wet body weight for the clams. Mean percent moisture was calculated using 10 organisms per test sediment exposed to Naval Station Pensacola turning basin sediments.

SPECIES	UNITS	PNSREF02	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
<i>Nereis virens</i>	%	0.814	1.66	1.94	0.868	0.862	0.616
<i>Macoma nasuta</i>	%	0.656	1.04	0.614	0.856	0.502	0.674

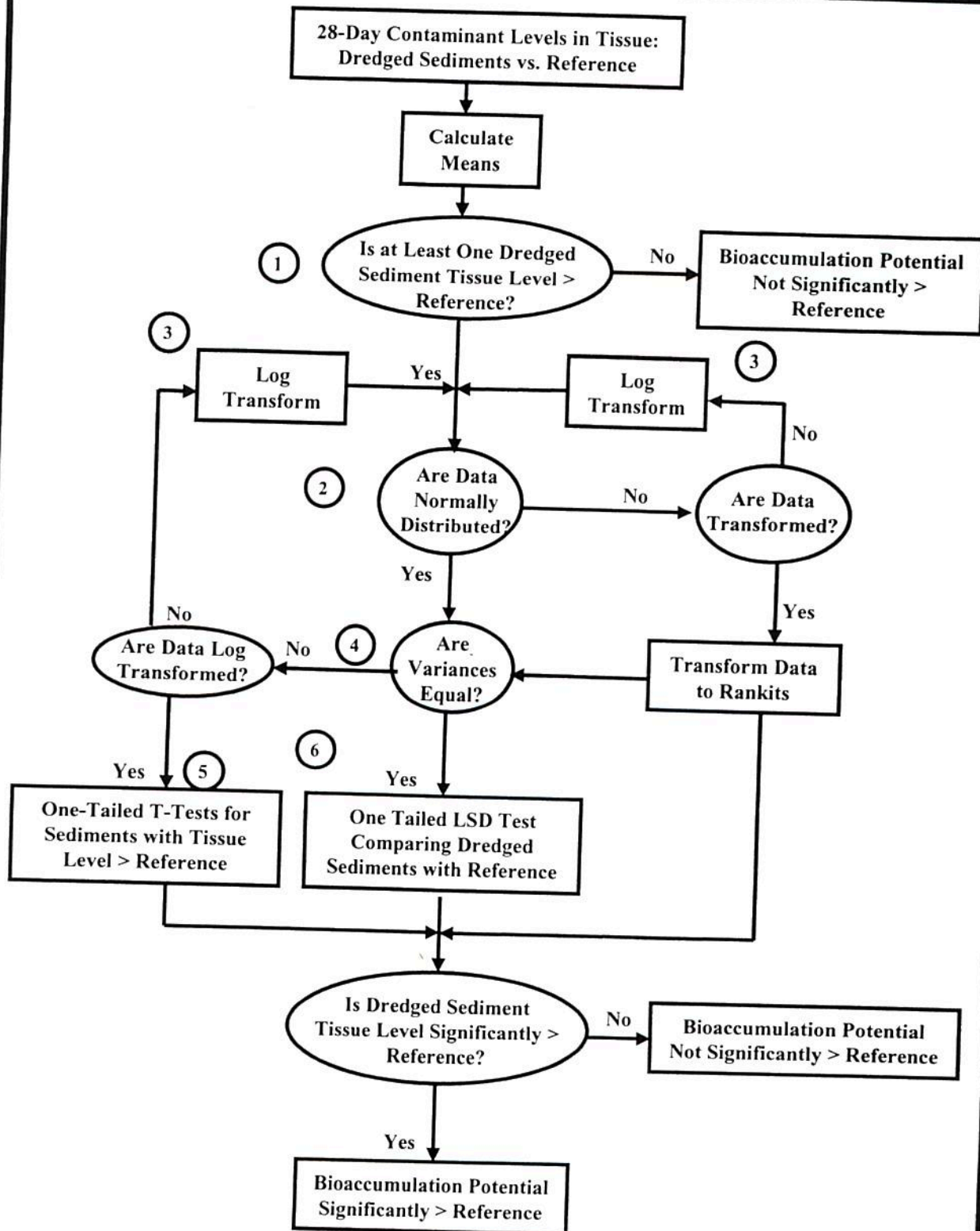
7.3 USEPA TOLERANCE/GUIDANCE LEVELS

The purpose of the bioaccumulation testing is to predict the potential for uptake of chemical contaminants in the dredged material by aquatic organisms. The detected tissue residue concentrations were compared to the USEPA Tolerance/Guidance Levels (USFDA 1998). These values are derived from risk assessment evaluations for application as critical limits for determining the acceptability of aquatic organisms as food sources to humans. Based on guidance in the ITM and the OTM, if tissue-residue concentrations are statistically lower than a USEPA Tolerance/Guidance Level, then the dredged material is suitable for open-water or ocean placement.

USEPA Guidance Levels exist for arsenic, cadmium, chromium, lead, nickel, total PCBs, aldrin+dielrin, chlordane, DDT+DDE+DDD, mirex, and total heptachlor. Upper 95 percent confidence levels of the mean tissue-residue concentrations for these constituents in worm and clam tissues exposed to Naval Station Pensacola sediments were compared to USEPA Guidance Levels (Tables 7-23 and 7-24). Results indicate that the tissue-residue concentrations for these constituents were statistically lower than the guidance levels in both the worm and the clam tissue residues.

7.4 LIMITING PERMISSIBLE CONCENTRATION (LPC) COMPLIANCE

Few contaminants of concern in organisms exposed to dredged material from Naval Station Pensacola turning basin statistically exceeded those of organisms exposed to reference sediment. Three metals (arsenic, copper, and zinc) had concentrations in worms that statistically exceeded the reference concentrations, however, the concentrations were nearly equivalent to concentrations in pre-test tissues. Two PAHs, one PCB congener and total PCB concentrations in clam tissue statistically exceeded the reference tissue, but the uptake ratios for each of these constituents were either less than or slightly greater than 1, indicating that concentrations for the test tissues were about the same as concentrations reported in the pre-test tissue (non-exposed tissue). Therefore, it is likely that the significant exceedances represent either natural or analytical variability of concentrations within the tissue sample, rather than contaminant uptake from the sediment. None of the tissue-residue concentrations for which USEPA Guidance Level exist exceeded the Guidance Levels. Therefore, the dredged material meets the LPC for bioaccumulation, and complies with the benthic criteria of Part 227.13 (c) (3).



Modified from: Inland Testing Manual (USEPA/USACE 1998)

FIGURE 7-1. DECISION TREE FOR STATISTICAL COMPARISONS AGAINST REFERENCE SITE

TABLE 7-1. SUMMARY OF WATER QUALITY PARAMETERS FROM 28-DAY BIOACCUMULATION TESTING WITH *Nereis virens* (SAND WORM)-NAVAL STATION PENSACOLA TURNING BASIN

Test Elutriate	Mean (\pm Standard Deviation)			
	Temperature ($^{\circ}$ C)	pH	Dissolved Oxygen (mg/L)	Salinity (ppt)
CONTROL	18.4-20.2 ^(a) 19.4 (\pm 0.5)	7.9-8.2 8.1 (\pm 0.1)	6.1-7.6 7.1 (\pm 0.3)	29.5-32.5 30.9 (\pm 0.8)
PNSREF02	17.6-20.3 ^(a) 19.2 (\pm 0.7)	8.0-8.3 8.1 (\pm 0.1)	5.9-7.5 6.8 (\pm 0.4)	28.9-32.1 30.8 (\pm 0.9)
PNS02-01	18.5-20.6 ^(a) 19.4 (\pm 0.5)	8.1-8.4 8.2 (\pm 0.1)	5.9-7.4 6.9 (\pm 0.4)	28.9-32.3 30.8 (\pm 0.9)
PNS02-02	18.6-20.1 ^(a) 19.4 (\pm 0.4)	7.9-8.3 8.1 (\pm 0.1)	6.0-7.5 6.9 (\pm 0.4)	28.9-32.3 30.9 (\pm 0.9)
PNS02-03	18.5-20.5 ^(a) 19.4 (\pm 0.5)	8.0-8.3 8.1 (\pm 0.1)	5.6-7.4 6.9 (\pm 0.4)	28.9-32.4 31.0 (\pm 0.9)
PNS02-04	17.9-20.0 ^(a) 19.0 (\pm 0.5)	8.1-8.3 8.1 (\pm 0.1)	5.9-7.6 7.0 (\pm 0.4)	28.8-32.4 30.9 (\pm 1.0)
PNS02-05	18.0-19.6 ^(a) 18.9 (\pm 0.4)	7.9-8.3 8.1 (\pm 0.1)	6.0-7.6 7.1 (\pm 0.4)	28.9-32.4 30.8 (\pm 1.0)

(a) Temperature was less than the target range of $20\pm 1^{\circ}$ C in several replicates.

TABLE 7-2. SUMMARY OF WATER QUALITY PARAMETERS FROM 28-DAY BIOACCUMULATION TESTING WITH *Macoma nasuta* (BLUNT-NOSED CLAM) –NAVAL STATION PENSACOLA TURNING BASIN

Test Elutriate	Mean (\pm Standard Deviation)			
	Temperature (°C)	pH	Dissolved Oxygen (mg/L)	Salinity (ppt)
CONTROL	10.5-13.2 ^(a) 12.5 (\pm 0.6)	7.9-8.2 8.0 (\pm 0.1)	6.9-8.9 8.3 (\pm 0.4)	29.8-32.3 31.0 (\pm 0.7)
PNSREF02	11.0-13.3 ^(a) 12.6 (\pm 0.5)	7.9-8.5 8.1 (\pm 0.1)	6.9-8.7 8.3 (\pm 0.4)	29.8-31.8 30.9 (\pm 0.6)
PNS02-01	12.1-13.4 ^(a) 12.8 (\pm 0.3)	8.0-8.3 8.1 (\pm 0.1)	6.8-8.5 8.1 (\pm 0.4)	29.6-32.0 30.9 (\pm 0.6)
PNS02-02	11.8-13.2 ^(a) 12.6 (\pm 0.3)	8.0-8.2 8.1 (\pm 0.1)	6.9-8.7 8.2 (\pm 0.4)	29.7-31.9 30.9 (\pm 0.6)
PNS02-03	11.6-12.8 12.3 (\pm 0.3)	8.0-8.2 8.1 (\pm 0.1)	7.0-8.8 8.2 (\pm 0.4)	29.5-31.7 30.9 (\pm 0.6)
PNS02-04	11.2-12.7 12.2 (\pm 0.3)	7.9-8.4 8.0 (\pm 0.1)	6.7-8.7 8.1 (\pm 0.4)	29.5-31.9 30.9 (\pm 0.7)
PNS02-05	11.7-13.0 12.3 (\pm 0.4)	7.9-8.4 8.1 (\pm 0.1)	7.0-8.8 8.1 (\pm 0.4)	29.7-31.9 30.9 (\pm 0.6)

(a) Temperature was outside the target range of $12\pm1^{\circ}\text{C}$ in several replicates.

**TABLE 7-3. RESULTS OF 28-DAY BIOACCUMULATION TESTING
(SURVIVAL) WITH *Nereis virens* (SAND WORM) –NAVAL STATION
PENSACOLA TURNING BASIN**

Test Sediment	No. Alive/ No. Exposed*	28-Day Percent Survival (percent)
CONTROL	60 / 60	100
PNSREF02	100 / 100	100
PNS02-01	100 / 102	98
PNS02-02	100 / 100	100
PNS02-03	99 / 100	100
PNS02-04	100 / 100	100
PNS02-05	100 / 100	100

* Total for 3 replicates of 20 animals for laboratory control sediment, 5 replicates of 20 animals for all other test sediments.

**TABLE 7-4. RESULTS OF 28-DAY BIOACCUMULATION TESTING
(SURVIVAL) WITH *Macoma nasuta* (BLUNT NOSE CLAM) –NAVAL
STATION PENSACOLA TURNING BASIN**

Test Sediment	No. Alive/ No. Exposed*	28-Day Percent Survival (percent)
CONTROL	149 / 150	99
PNSREF02	245 / 250	98
PNS02-01	243 / 250	97
PNS02-02	246 / 250	98
PNS02-03	242 / 250	97
PNS02-04	232 / 250	93
PNS02-05	243 / 250	97

* Total for 3 replicates of 50 animals for laboratory control sediment, 5 replicates of 50 animals for all other test sediments.

TABLE 7-5. RESULTS OF REFERENCE TOXICANT TESTING ON ACQUIRED LOTS OF TEST ORGANISMS

<u>Test Species</u>	<u>Organism Lot Number</u>	<u>Reference Toxicant</u>	<u>Test Endpoint</u>	<u>Acceptable Control Chart Limits</u>
<i>Nereis virens</i>	NV-026	Sodium dodecyl sulfate (SDS)	48-hour LC50: 9.4 mg/L SDS	0-53.3 mg/L SDS
<i>Macoma nasuta</i>	MA-019	Sodium dodecyl sulfate (SDS)	48-hour LC50: 116.0 mg/L SDS	21.2-118.7 mg/L SDS

**TABLE 7-6 REQUIRED CONTAINERS, PRESERVATION TECHNIQUES,
AND HOLDING TIMES FOR TISSUE SAMPLES ^(a)**

Parameter	Mass Required (g) ^(b)	Container	Preservative	Holding Time
Inorganics				
Mercury	5	G	Frozen, $\leq -20^{\circ}\text{C}$	28 days
Other Metals	5	G	Frozen, $\leq -20^{\circ}\text{C}$	Up to 6 months to analysis
Organics				
PAHs, Chlorinated Pesticides, PCB Congeners	40	G	Frozen, $\leq -20^{\circ}\text{C}$	Up to 1 year to analysis
Lipids	10	G	Frozen, $\leq -20^{\circ}\text{C}$	Up to 1 year to analysis

(a) From time of sample collection.

(b) Additional volume will need to be provided for samples designated as MS/MSD/MDs

**TABLE 7-7. NAVAL STATION PENSACOLA TURNING BASIN: MEAN PAH
CONCENTRATIONS (UG/KG) IN *Nereis virens* (SAND WORM)**

ANALYTE	UNITS	MDL	PNSREF02	PNS02-01	PNS02-02
1-METHYLNAPHTHALENE	UG/KG	8	ND	ND	ND
2-METHYLNAPHTHALENE	UG/KG	8	ND	ND	ND
ACENAPHTHENE	UG/KG	8	ND	ND	3.48
ACENAPHTHYLENE	UG/KG	8	ND	ND	ND
ANTHRACENE	UG/KG	8	ND	ND	ND
BENZ(A)ANTHRACENE	UG/KG	8	ND	ND	3.52
BENZO(A)PYRENE	UG/KG	8	ND	ND	ND
BENZO(B)FLUORANTHENE	UG/KG	8	ND	ND	ND
BENZO(GHI)PERYLENE	UG/KG	8	ND	ND	ND
BENZO(K)FLUORANTHENE	UG/KG	8	ND	ND	ND
CHRYSENE	UG/KG	8	ND	ND	3.52
DIBENZ(A,H)ANTHRACENE	UG/KG	8	ND	ND	ND
FLUORANTHENE	UG/KG	8	ND	4.04	3.58
FLUORENE	UG/KG	8	ND	ND	ND
INDENO(1,2,3-CD)PYRENE	UG/KG	8	ND	ND	ND
NAPHTHALENE	UG/KG	8	ND	ND	ND
PHENANTHRENE	UG/KG	8	ND	ND	3.9
PYRENE	UG/KG	8	ND	3.62	3.94
TOTAL PAHS (ND=RL)	UG/KG	--	144	142	132

PAHs were not tested for PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses.

***NOTE:** Shaded and bold values indicate sites where mean tissue residues are significantly higher than the mean reference tissue ($p < 0.05$).

MDL = method detection limit

ND = not detected in any of the five tested tissue replicates

TABLE 7-8. NAVAL STATION PENSACOLA: UPTAKE RATIOS (URs) FOR PAHs IN *Nereis virens* (SAND WORM)

ANALYTE	PNSREF02	PNS02-01	PNS02-02
1-METHYLNAPHTHALENE	ND	ND	ND
2-METHYLNAPHTHALENE	ND	ND	ND
ACENAPHTHENE	ND	ND	ND
ACENAPHTHYLENE	ND	ND	0.87
ANTHRACENE	ND	ND	ND
BENZ(A)ANTHRACENE	ND	ND	ND
BENZO(A)PYRENE	ND	ND	0.88
BENZO(B)FLUORANTHENE	ND	ND	ND
BENZO(GHI)PERYLENE	ND	ND	ND
BENZO(K)FLUORANTHENE	ND	ND	ND
CHRYSENE	ND	ND	ND
DIBENZ(A,H)ANTHRACENE	ND	ND	0.88
FLUORANTHENE	ND	ND	ND
FLUORENE	ND	1.01	0.89
INDENO(1,2,3-CD)PYRENE	ND	ND	ND
NAPHTHALENE	ND	ND	ND
PHENANTHRENE	ND	ND	ND
PYRENE	ND	ND	0.97
TOTAL PAHS (ND=RL)	1.04	0.91	0.98
		1.03	0.95

PAHs were not tested for PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses

NOTE: Shaded and bold values indicate uptake ratios for mean tissue residues that statistically exceeded the reference tissue residue

ND = not detected in any of the five tested tissue replicates

URs>1 when the mean analyte concentration in test tissue is higher than the mean analyte concentration in the pre-test tissue

TABLE 7-9. NAVAL STATION PENSACOLA TURNING BASIN: MEAN PAH CONCENTRATIONS (UG/KG) IN *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE	UNITS	RL	PNSREF02	PNS02-01	PNS02-02
1-METHYLNAPHTHALENE	UG/KG	8	ND	ND	ND
2-METHYLNAPHTHALENE	UG/KG	8	ND	ND	ND
ACENAPHTHENE	UG/KG	8	ND	ND	ND
ACENAPHTHYLENE	UG/KG	8	ND	ND	ND
ANTHRACENE	UG/KG	8	ND	ND	ND
BENZ(A)ANTHRACENE	UG/KG	8	ND	ND	ND
BENZO(A)PYRENE	UG/KG	8	ND	ND	3.06
BENZO(B)FLUORANTHENE	UG/KG	8	ND	ND	ND
BENZO(GHI)PERYLENE	UG/KG	8	3.66	ND	3.58
BENZO(K)FLUORANTHENE	UG/KG	8	ND	ND	ND
CHRYSENE	UG/KG	8	ND	ND	ND
DIBENZ(A,H)ANTHRACENE	UG/KG	8	ND	ND	ND
FLUORANTHENE	UG/KG	8	ND	ND	ND
FLUORENE	UG/KG	8	3.4	3.06	6.48 *
INDENO(1,2,3-CD)PYRENE	UG/KG	8	ND	ND	ND
NAPHTHALENE	UG/KG	8	ND	ND	ND
PHENANTHRENE	UG/KG	8	3.5	ND	ND
PYRENE	UG/KG	8	ND	ND	3.36
TOTAL PAHS (ND=RL)	UG/KG	--	3.62	3.72	11.1 *
			138	140	137

PAHs were not tested for PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses.

NOTE: Shaded and bold values indicate sites where mean tissue residues are significantly higher than the mean reference tissue ($p < 0.05$).

RL = average reporting limit

ND = not detected in any of the five tested tissue replicates

TABLE 7-10. NAVAL STATION PENSACOLA: UPTAKE RATIOS (URs)
FOR PAHs IN *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE	PNSREF02	PNS02-01	PNS02-02
1-METHYLNAPHTHALENE	ND	ND	ND
2-METHYLNAPHTHALENE	ND	ND	ND
ACENAPHTHENE	ND	ND	ND
ACENAPHTHYLENE	ND	ND	ND
ANTHRACENE	ND	ND	ND
BENZ(A)ANTHRACENE	ND	ND	ND
BENZO(A)PYRENE	ND	ND	0.77
BENZO(B)FLUORANTHENE	0.92	ND	ND
BENZO(GHI)PERYLENE	ND	ND	0.89
BENZO(K)FLUORANTHENE	ND	ND	ND
CHRYSENE	ND	ND	ND
DIBENZ(A,H)ANTHRACENE	ND	ND	ND
FLUORANTHENE	0.92	ND	ND
FLUORENE	ND	0.83	1.75 *
INDENO(1,2,3-CD)PYRENE	ND	ND	ND
NAPHTHALENE	0.88	ND	ND
PHENANTHRENE	ND	ND	ND
PYRENE	1.21	ND	0.84
TOTAL PAHS (ND=RL)	1.07	1.24	3.70 *
		1.08	1.06

PAHs were not tested for PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses

NOTE: Shaded and bold values indicate uptake ratios for mean tissue residues that statistically exceeded the reference tissue residue

ND = not detected in any of the five tested tissue replicates

URs>1 when the mean analyte concentration in test tissue is higher than the mean analyte concentration in the pre-test tissue

TABLE 7-11. NAVAL STATION PENSACOLA TURNING BASIN: MEAN METAL CONCENTRATIONS (MG/KG)
IN *Nereis virens* (SAND WORM)

ANALYTE	UNITS	RL	PNSREF02	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
ALUMINUM	MG/KG	20	17.4	9.68	9.42	18.8	14.6	15.2
ANTIMONY	MG/KG	1	ND	ND	0.436	ND	ND	ND
ARSENIC	MG/KG	1	2.68	3.06	2.64	2.64	2.36	3.24 *
BERYLLIUM	MG/KG	0.4	ND	ND	ND	0.172	0.184	0.212
CADMIUM	MG/KG	0.5	ND	ND	ND	ND	ND	ND
CHROMIUM	MG/KG	0.5	0.238	0.204	0.19	0.226	0.212	0.202
COBALT	MG/KG	5	ND	ND	ND	2.03	2.03	ND
COPPER	MG/KG	2.5	1.32	1.86 *	1.42	1.6	1.48	1.26
IRON	MG/KG	10	69.2	48.2	40	60.5	46.2	42.3
LEAD	MG/KG	0.3	0.33	0.242	0.318	0.3	0.25	0.224
MANGANESE	MG/KG	1.5	0.684	0.408	0.632	0.856	0.498	0.67
MERCURY	MG/KG	0.033	0.036	0.0268	0.03	0.0484	0.0442	0.0438
NICKEL	MG/KG	4	ND	ND	ND	ND	ND	ND
SELENIUM	MG/KG	0.5	0.566	0.592	0.67	0.678	0.56	0.534
SILVER	MG/KG	0.5	ND	ND	ND	ND	ND	ND
THALLIUM	MG/KG	1.07	ND	ND	ND	ND	ND	ND
TIN	MG/KG	10	3.88	4.06	3.9	4.2	4.02	3.98
ZINC	MG/KG	2	9.48	10.2	18.7	14.3 *	13.6 *	18.6

*NOTE: Shaded and bold values indicate sites where mean tissue residues are significantly higher than the reference site ($p < 0.05$).

RL = average reporting limit

ND = not detected in any of the five tested tissue replicates

TABLE 7-12. NAVAL STATION PENSACOLA: UPTAKE RATIOS (URs) FOR METALS IN
Nereis virens (SAND WORM)

ANALYTE	PNSREF02	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
ALUMINUM	0.12	0.07	0.07	0.13	0.1	0.11
ANTIMONY	ND	ND	0.87	ND	ND	ND
ARSENIC	0.9	1.03	0.89	0.89	0.8	1.09 *
BERYLLIUM	ND	ND	ND	0.67	0.72	0.83
CADMIUM	ND	ND	ND	ND	ND	ND
CHROMIUM	0.35	0.3	0.28	0.33	0.31	0.3
COBALT	ND	ND	ND	2.03	2.03	ND
COPPER	0.51	0.72 *	0.55	0.62	0.58	0.49
IRON	0.24	0.17	0.14	0.21	0.16	0.15
LEAD	0.71	0.52	0.69	0.65	0.54	0.48
MANGANESE	0.16	0.09	0.14	0.2	0.11	0.15
MERCURY	0.55	0.41	0.45	0.73	0.67	0.66
NICKEL	ND	ND	ND	ND	ND	ND
SELENIUM	0.88	0.92	1.05	1.06	0.88	0.83
SILVER	ND	ND	ND	ND	ND	ND
THALLIUM	ND	ND	ND	ND	ND	ND
TIN	0.95	0.99	0.95	1.02	0.98	0.97
ZINC	0.7	0.76	1.39	1.06 *	1.01 *	1.38

NOTE: Shaded and bold values indicate uptake ratios for mean tissue residues that statistically exceeded the reference tissue residue
 ND = not detected in any of the five tested tissue replicates
 URs>1 when the mean analyte concentration in test tissue is higher than the mean analyte concentration in the pre-test tissue

TABLE 7-13. NAVAL STATION PENSACOLA TURNING BASIN: MEAN METAL CONCENTRATIONS (MG/KG)
IN *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE	UNITS	RL	PNSREF02	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
ALUMINUM	MG/KG	20	37.6	17.5	26.1	28	17.4	22.9
ANTIMONY	MG/KG	1	0.362	0.454	0.312	0.236	0.344	0.252
ARSENIC	MG/KG	1	3.76	3.6	3.74	3.78	3.94	3.84
BERYLLIUM	MG/KG	0.4	0.194	ND	0.196	0.2	0.19	0.23
CADMIUM	MG/KG	0.5	ND	ND	ND	ND	ND	ND
CHROMIUM	MG/KG	0.5	0.31	0.264	0.294	0.264	0.256	0.266
COBALT	MG/KG	5	1.58	1.58	2.04	1.56	2.03	1.56
COPPER	MG/KG	2.5	4.42	4.24	4.46	3.16	2.5	2.66
IRON	MG/KG	10	136	122	128	114	59.7	98.3
LEAD	MG/KG	0.3	0.552	0.426	0.624	0.424	0.382	0.452
MANGANESE	MG/KG	1.5	3	1.25	3.04	2.7	0.736	1.9
MERCURY	MG/KG	0.033	0.0458	0.04	0.0394	0.0282	0.029	0.0272
NICKEL	MG/KG	4	0.848	1.14	0.59	1.41	0.844	0.576
SELENIUM	MG/KG	0.5	0.54	0.442	0.526	0.47	0.504	0.51
SILVER	MG/KG	0.5	ND	ND	ND	ND	ND	ND
THALLIUM	MG/KG	1	ND	ND	ND	ND	ND	ND
TIN	MG/KG	10	3.48	3.56	3.52	3.5	3.46	3.56
ZINC	MG/KG	2	19.7	18.7	19.4	17.9	17.3	19.9

*NOTE: Shaded and bold values indicate sites where mean tissue residues are significantly higher than the reference site ($p < 0.05$).

RL = average reporting limit

ND = not detected in any of the five tested tissue replicates

TABLE 7-14. NAVAL STATION PENSACOLA: UPTAKE RATIOS (URs) FOR METALS IN *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE	PNSREF02	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
ALUMINUM	0.6	0.28	0.42	0.45	0.28	0.37
ANTIMONY	1.32	1.66	1.14	0.86	1.26	0.92
ARSENIC	0.92	0.88	0.91	0.92	0.96	0.94
BERYLLIUM	0.91	ND	0.92	0.94	0.89	1.08
CADMIUM	ND	ND	ND	ND	ND	ND
CHROMIUM	0.74	0.63	0.71	0.63	0.61	0.64
COBALT	0.63	0.63	0.82	0.62	0.81	0.62
COPPER	1.4	1.34	1.41	1	0.79	0.84
IRON	0.96	0.86	0.9	0.8	0.42	0.69
LEAD	1.25	0.96	1.41	0.96	0.86	1.02
MANGANESE	1.37	0.57	1.39	1.23	0.34	0.87
MERCURY	1.86	1.62	1.6	1.14	1.18	1.1
NICKEL	0.55	0.73	0.38	0.91	0.55	0.37
SELENIUM	0.86	0.71	0.84	0.75	0.8	0.81
SILVER	ND	ND	ND	ND	ND	ND
THALLIUM	ND	ND	ND	ND	ND	ND
TIN	0.85	0.87	0.86	0.85	0.84	0.87
ZINC	1.02	0.96	1	0.92	0.89	1.02

NOTE: Shaded and bold values indicate uptake ratios for mean tissue residues that statistically exceeded the reference tissue residue
 ND = not detected in any of the five tested tissue replicates

URs>1 when the mean analyte concentration in test tissue is higher than the mean analyte concentration in the pre-test tissue

**TABLE 7-15. NAVAL STATION PENSACOLA TURNING BASIN: MEAN PCBs
CONCENTRATIONS (UG/KG) IN *Nereis virens* (SAND WORM)**

ANALYTE	UNITS	RL	PNSREF02	PNS02-01	PNS02-02
BZ# 8*	UG/KG	2	1.56	2.18	2.06
BZ# 18*	UG/KG	2	1.08	1.16	ND
BZ# 28*	UG/KG	2	ND	ND	ND
BZ# 44*	UG/KG	2	ND	ND	ND
BZ# 49	UG/KG	2	ND	1.06	ND
BZ# 52*	UG/KG	2	ND	1.08	ND
BZ# 66*	UG/KG	2	ND	ND	ND
BZ# 77*	UG/KG	2	0.992	1.15	1.02
BZ# 87	UG/KG	2	ND	ND	ND
BZ# 101*	UG/KG	2	ND	1.34	ND
BZ# 105*	UG/KG	2	ND	ND	ND
BZ# 118*	UG/KG	2	ND	1.32	ND
BZ# 126*	UG/KG	2	ND	ND	ND
BZ# 128*	UG/KG	2	ND	ND	ND
BZ# 138*	UG/KG	2	0.954	1.64	0.936
BZ# 153*	UG/KG	2	1.16	1.74	1.04
BZ# 156	UG/KG	2	ND	ND	ND
BZ# 169*	UG/KG	2	ND	ND	ND
BZ# 170*	UG/KG	2	ND	ND	ND
BZ# 180*	UG/KG	2	0.96	1.02	ND
BZ# 183	UG/KG	2	ND	0.992	ND
BZ# 184	UG/KG	2	ND	ND	ND
BZ# 187*	UG/KG	2	ND	1.12	ND
BZ# 195	UG/KG	2	ND	ND	ND
BZ# 206	UG/KG	2	ND	ND	ND
BZ# 209	UG/KG	2	ND	ND	ND
TOTAL PCBs (ND=RL)	UG/KG	--	66.6	69.1	67.7

PCB congeners were not tested for PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses.

* PCB congeners used for Total PCB summation, as per Table 9-3 of the ITM (USEPA/USACE 1998)

****NOTE:** Shaded and bold values indicate sites where mean tissue residues are significantly higher than the mean reference tissue ($p < 0.05$).

RL = average reporting limit

ND = not detected in any of the five tested tissue replicates

TABLE 7-16. NAVAL STATION PENSACOLA: UPTAKE RATIOS
(URs) FOR PCBs IN *Nereis virens* (SAND WORM)

ANALYTE	PNSREF02	PNS02-01	PNS02-02
BZ# 8*	0.6	0.84	0.79
BZ# 18*	0.72	0.77	ND
BZ# 28*	ND	ND	ND
BZ# 44*	ND	ND	ND
BZ# 49	ND	1.06	ND
BZ# 52*	ND	1.08	ND
BZ# 66*	ND	ND	ND
BZ# 77*	0.99	1.15	1.02
BZ# 87	ND	ND	ND
BZ# 101*	ND	1.34	ND
BZ# 105*	ND	ND	ND
BZ# 118*	ND	1.32	ND
BZ# 126*	ND	ND	ND
BZ# 128*	ND	ND	ND
BZ# 138*	0.95	1.63	0.93
BZ# 153*	0.97	1.45	0.86
BZ# 156	ND	ND	ND
BZ# 169*	ND	ND	ND
BZ# 170*	ND	ND	ND
BZ# 180*	0.96	1.02	ND
BZ# 183	ND	0.99	ND
BZ# 184	ND	ND	ND
BZ# 187*	ND	1.12	ND
BZ# 195	ND	ND	ND
BZ# 206	ND	ND	ND
BZ# 209	ND	ND	ND
TOTAL PCBs (ND=RL)	0.96	1	0.98

PCB congeners were not tested for PNS02-03, PNS02-04, and PNS02-05
based on the results of the sediment chemistry analyses

NOTE: Shaded and bold values indicate uptake ratios for mean tissue residues that
statistically exceeded the reference tissue residue

ND = not detected in any of the five tested tissue replicates

URs>1 when the mean analyte concentration in test tissue is higher than the
mean analyte concentration in the pre-test tissue

* PCB congeners used for Total PCB summation, as per Table 9-3 of the ITM (USEPA/USACE 1998)

TABLE 7-17. NAVAL STATION PENSACOLA TURNING BASIN: MEAN PCBs CONCENTRATIONS (MG/KG) IN *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE	UNITS	RL	PNSREF02	PNS02-01	PNS02-02
BZ# 8*	UG/KG	2	2.04	2.74**	3.38
BZ# 18*	UG/KG	2	1.09	1.14	1.02
BZ# 28*	UG/KG	2	ND	ND	ND
BZ# 44*	UG/KG	2	ND	ND	ND
BZ# 49	UG/KG	2	ND	1.08	1.04
BZ# 52*	UG/KG	2	ND	ND	ND
BZ# 66*	UG/KG	2	ND	ND	ND
BZ# 77*	UG/KG	2	ND	ND	ND
BZ# 87	UG/KG	2	ND	ND	ND
BZ# 101*	UG/KG	2	ND	ND	ND
BZ# 105*	UG/KG	2	ND	ND	ND
BZ# 118*	UG/KG	2	ND	ND	ND
BZ# 126*	UG/KG	2	ND	ND	ND
BZ# 128*	UG/KG	2	ND	ND	ND
BZ# 138*	UG/KG	2	ND	ND	0.988
BZ# 153*	UG/KG	2	ND	ND	0.974
BZ# 156	UG/KG	2	ND	ND	ND
BZ# 169*	UG/KG	2	ND	ND	ND
BZ# 170*	UG/KG	2	ND	ND	ND
BZ# 180*	UG/KG	2	ND	ND	ND
BZ# 183	UG/KG	2	ND	ND	ND
BZ# 184	UG/KG	2	ND	ND	ND
BZ# 187*	UG/KG	2	ND	ND	ND
BZ# 195	UG/KG	2	ND	ND	ND
BZ# 206	UG/KG	2	ND	ND	ND
BZ# 209	UG/KG	2	ND	ND	ND
TOTAL PCBs (ND=RL)	UG/KG	--	70.7	72.6**	73.5

PCB congeners were not tested for PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses.

* PCB congeners used for Total PCB summation, as per Table 9-3 of the ITM (USEPA/USACE 1998)

**NOTE: Shaded and bold values indicate sites where mean tissue residues are significantly higher than the mean reference tissue ($p < 0.05$).

RL = average reporting limit

ND = not detected in any of the five tested tissue replicates

TABLE 7-18. NAVAL STATION PENSACOLA: UPTAKE RATIOS
(URs) FOR PCBs IN *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE	PNSREF02	PNS02-01	PNS02-02
BZ# 8*	0.72	0.97	1.19
BZ# 18*	0.97		0.91
BZ# 28*	ND	1.02	ND
BZ# 44*	ND	ND	ND
BZ# 49	ND	ND	ND
BZ# 52*	ND	1.08	1.04
BZ# 66*	ND	ND	ND
BZ# 77*	ND	ND	ND
BZ# 87	ND	ND	ND
BZ# 101*	ND	ND	ND
BZ# 105*	ND	ND	ND
BZ# 118*	ND	ND	ND
BZ# 126*	ND	ND	ND
BZ# 128*	ND	ND	ND
BZ# 138*	ND	ND	ND
BZ# 153*	ND	ND	0.99
BZ# 156	ND	ND	0.97
BZ# 169*	ND	ND	ND
BZ# 170*	ND	ND	ND
BZ# 180*	ND	ND	ND
BZ# 183	ND	ND	ND
BZ# 184	ND	ND	ND
BZ# 187*	ND	ND	ND
BZ# 195	ND	ND	ND
BZ# 206	ND	ND	ND
BZ# 209	ND	ND	ND
TOTAL PCBs (ND=RL)	0.98	1.01	1.02

PCB congeners were not tested for PNS02-03, PNS02-04, and PNS02-05
based on the results of the sediment chemistry analyses

NOTE: Shaded and bold values indicate uptake ratios for mean tissue residues that
statistically exceeded the reference tissue residue

ND = not detected in any of the five tested tissue replicates

URs > 1 when the mean analyte concentration in test tissue is higher than the
mean analyte concentration in the pre-test tissue

* PCB congeners used for Total PCB summation, as per Table 9-3 of the ITM (USEPA/USACE 1998)

**TABLE 7-19. NAVAL STATION PENSACOLA TURNING BASIN: MEAN
CHLORINATED PESTICIDE CONCENTRATIONS (UG/KG) IN *Nereis*
virens (SAND WORM)**

ANALYTE	UNITS	RL	PNSREF02	PNS02-01
4,4'-DDD	UG/KG	1.7	0.744	0.782
4,4'-DDE	UG/KG	1.7	0.76	0.606
4,4'-DDT	UG/KG	1.7	ND	ND
ALDRIN	UG/KG	1.7	ND	ND
ALPHA-BHC	UG/KG	1.7	ND	ND
BETA-BHC	UG/KG	1.7	ND	ND
CHLOROBENSIDE	UG/KG	3.3	ND	ND
CHLORDANE	UG/KG	17	ND	ND
DACHTAL	UG/KG	3.3	ND	ND
DELTA-BHC	UG/KG	1.7	ND	ND
DIELDRIN	UG/KG	1.7	ND	ND
ENDOSULFAN I	UG/KG	1.7	ND	ND
ENDOSULFAN II	UG/KG	1.7	ND	ND
ENDOSULFAN SULFATE	UG/KG	1.7	ND	ND
ENDRIN	UG/KG	1.7	ND	1.12
ENDRIN ALDEHYDE	UG/KG	1.7	ND	ND
GAMMA-BHC	UG/KG	1.7	ND	ND
HEPTACHLOR	UG/KG	1.7	ND	ND
HEPTACHLOR EPOXIDE	UG/KG	1.7	ND	ND
METHOXYCHLOR	UG/KG	3.3	ND	ND
MIREX	UG/KG	1.7	ND	ND
TOXAPHENE	UG/KG	67	ND	ND

Chlorinated pesticides were not tested for PNS02-02, PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses.

***NOTE:** Shaded and bold values indicate sites where mean tissue residues are significantly higher than the mean reference tissue ($p < 0.05$).

RL = average reporting limit

ND = not detected in any of the five tested tissue replicates

TABLE 7-20. NAVAL STATION PENSACOLA: UPTAKE RATIOS (URs) FOR CHLORINATED PESTICIDE IN *Nereis virens* (SAND WORM)

ANALYTE	PNSREF02	PNS02-01
4,4'-DDD	1.11	1.17
4,4'-DDE	0.89	0.71
4,4'-DDT	ND	ND
ALDRIN	ND	ND
ALPHA-BHC	ND	ND
BETA-BHC	ND	ND
CHLOROBENSIDE	ND	ND
CHLORDANE	ND	ND
DACHTAL	ND	ND
DELTA-BHC	ND	ND
DIELDRIN	ND	ND
ENDOSULFAN I	ND	ND
ENDOSULFAN II	ND	ND
ENDOSULFAN SULFATE	ND	ND
ENDRIN	ND	1.32
ENDRIN ALDEHYDE	ND	ND
GAMMA-BHC	ND	ND
HEPTACHLOR	ND	ND
HEPTACHLOR EPOXIDE	ND	ND
METHOXYCHLOR	ND	ND
MIREX	ND	ND
TOXAPHENE	ND	ND

Chlorinated pesticides were not tested for PNS02-02, PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses

NOTE: Shaded and bold values indicate uptake ratios for mean tissue residues that statistically exceeded the reference tissue residue

ND = not detected in any of the five tested tissue replicates

URs>1 when the mean analyte concentration in test tissue is higher than the mean analyte concentration in the pre-test tissue

TABLE 7-21. NAVAL STATION PENSACOLA TURNING BASIN: MEAN CHLORINATED PESTICIDE CONCENTRATIONS (MG/KG) IN *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE	UNITS	RL	PNSREF02	PNS02-01
4,4'-DDD	UG/KG	1.7	ND	0.766
4,4'-DDE	UG/KG	1.7	0.76	ND
4,4'-DDT	UG/KG	1.7	1.09	0.854
ALDRIN	UG/KG	1.7	ND	0.782
ALPHA-BHC	UG/KG	1.7	ND	ND
BETA-BHC	UG/KG	1.7	ND	ND
CHLOROBENSIDE	UG/KG	3.3	ND	ND
CHLORDANE	UG/KG	17	ND	ND
DACHTAL	UG/KG	3.3	ND	ND
DELTA-BHC	UG/KG	1.7	ND	ND
DIELDRIN	UG/KG	1.7	ND	ND
ENDOSULFAN I	UG/KG	1.7	ND	ND
ENDOSULFAN II	UG/KG	1.7	0.752	0.808
ENDOSULFAN SULFATE	UG/KG	1.7	ND	ND
ENDRIN	UG/KG	1.7	ND	ND
ENDRIN ALDEHYDE	UG/KG	1.7	ND	ND
GAMMA-BHC	UG/KG	1.7	ND	ND
HEPTACHLOR	UG/KG	1.7	ND	ND
HEPTACHLOR EPOXIDE	UG/KG	1.7	ND	ND
METHOXYCHLOR	UG/KG	3.3	ND	ND
MIREX	UG/KG	1.7	ND	ND
TOXAPHENE	UG/KG	67	ND	ND

Chlorinated pesticides were not tested for PNS02-02, PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses.

***NOTE:** Shaded and bold values indicate sites where mean tissue residues are significantly higher than the mean reference tissue ($p < 0.05$).

RL = average reporting limit

ND = not detected in any of the five tested tissue replicates

TABLE 7-22. NAVAL STATION PENSACOLA: UPTAKE RATIOS (URs) FOR CHLORINATED PESTICIDE IN *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE	PNSREF02	PNS02-01
4,4'-DDD	ND	0.9
4,4'-DDE	0.99	ND
4,4'-DDT	1.28	1
ALDRIN	ND	0.92
ALPHA-BHC	ND	ND
BETA-BHC	ND	ND
CHLOROBENSIDE	ND	ND
CHLORDANE	ND	ND
DACHTAL	ND	ND
DELTA-BHC	ND	ND
DIELDRIN	ND	ND
ENDOSULFAN I	ND	ND
ENDOSULFAN II	0.88	0.95
ENDOSULFAN SULFATE	ND	ND
ENDRIN	ND	ND
ENDRIN ALDEHYDE	ND	ND
GAMMA-BHC	ND	ND
HEPTACHLOR	ND	ND
HEPTACHLOR EPOXIDE	ND	ND
METHOXYCHLOR	ND	ND
MIREX	ND	ND
TOXAPHENE	ND	ND

Chlorinated pesticides were not tested for PNS02-02, PNS02-03, PNS02-04, and PNS02-05 based on the results of the sediment chemistry analyses

NOTE: Shaded and bold values indicate uptake ratios for mean tissue residues that statistically exceeded the reference tissue residue

ND = not detected in any of the five tested tissue replicates

URs>1 when the mean analyte concentration in test tissue is higher than the mean analyte concentration in the pre-test tissue

TABLE 7-23. COMPARISON OF UPPER 95% CONFIDENCE LEVELS OF THE MEAN CONCENTRATION TO USEPA TOLERANCE/GUIDANCE LEVELS^(a) FOR *Nereis virens* (SAND WORM)

ANALYTE ^(b)	USEPA GUIDANCE		PNSREF02	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
	LEVEL	UNITS						
ARSENIC	86	MG/KG	2.90	3.15	2.77	2.85	2.47	3.55
CADMIUM	4	MG/KG	0.07	0.07	0.07	0.07	0.07	0.07
CHROMIUM	13	MG/KG	0.30	0.24	0.20	0.29	0.24	0.22
LEAD	1.7	MG/KG	0.39	0.34	0.36	0.35	0.32	0.30
METHYL MERCURY	1	MG/KG	0.04	0.03	0.03	0.05	0.05	0.05
NICKEL	80	MG/KG	0.24	0.24	0.24	0.24	0.24	0.24
TOTAL PCB (ND=0)	2000	UG/KG	10.45	31.76	8.86	NT	NT	NT
TOTAL PCB (ND=1/2DL)	2000	UG/KG	22.60	40.93	21.74	NT	NT	NT
ALDRIN+DIELDRIN	300	UG/KG	0.67	0.67	NT	NT	NT	NT
CHLORDANE	300	UG/KG	4.15	4.15	NT	NT	NT	NT
DDT+DDD+DDE	5000	UG/KG	0.42	0.42	NT	NT	NT	NT
MIREX	100	UG/KG	0.60	0.60	NT	NT	NT	NT
TOTAL HEPTACHLOR	300	UG/KG	0.44	0.44	NT	NT	NT	NT

(a) primary reference for all values: (USFDA 1998) *Fish and Fishery Products Hazards and Control Guide*.
U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition. January.

(b) Values provided only for chemical constituents tested and relevant to this project.

TABLE 7-24. COMPARISON OF UPPER 95% CONFIDENCE LEVELS OF THE MEAN CONCENTRATION TO USEPA TOLERANCE/GUIDANCE LEVELS^(a) FOR *Macoma nasuta* (BLUNT-NOSE CLAM)

ANALYTE ^(b)	USEPA GUIDANCE LEVEL	UNITS	PNSREF02	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
ARSENIC	86	MG/KG	4.09	4.20	4.22	4.30	4.52	4.17
CADMIUM	4	MG/KG	0.07	0.07	0.07	0.07	0.07	0.07
CHROMIUM	13	MG/KG	0.38	0.29	0.34	0.29	0.37	0.29
LEAD	1.7	MG/KG	0.77	0.46	0.69	0.45	0.42	0.52
METHYL MERCURY	1	MG/KG	0.05	0.04	0.04	0.03	0.03	0.03
NICKEL	80	MG/KG	0.63	0.60	0.66	0.51	0.64	0.61
TOTAL PCB (ND=0)	2000	UG/KG	6.91	8.36	9.74	NT	NT	NT
TOTAL PCB (ND=1/2DL)	2000	UG/KG	20.54	22.28	24.04	NT	NT	NT
ALDRIN+DIELDRIN	300	UG/KG	0.67	0.50	NT	NT	NT	NT
CHLORDANE	300	UG/KG	4.15	4.15	NT	NT	NT	NT
DDT+DDD+DDE	5000	UG/KG	0.21	0.19	NT	NT	NT	NT
MIREX	100	UG/KG	0.60	0.60	NT	NT	NT	NT
TOTAL HEPTACHLOR	300	UG/KG	0.44	0.44	NT	NT	NT	NT

(a) primary reference for all values: (USFDA 1998) *Fish and Fishery Products Hazards and Control Guide*.
U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition. January.

(b) Values provided only for chemical constituents tested and relevant to this project.
NT = not tested

8. SUMMARY AND CONCLUSIONS

Results of the bulk sediment, elutriate, toxicity, and bioaccumulation studies are presented in Chapters 4, 5, 6, and 7, respectively. This chapter summarizes the results of each testing component, and discusses the overall results of the combined testing program. The comprehensive results of the testing program provide information regarding the physical, chemical, and ecotoxicological characteristics of the sediment in Naval Station Pensacola turning basin.

8.1 BULK SEDIMENT CHEMISTRY

The sediment proposed for dredging and placement from the Naval Station Pensacola turning basin was primarily comprised of sand (51.9-88.1 percent) at locations PNS02-01, PNS02-02, and PNS02-05, and predominately comprised of silt-clay (60 and 69.7 percent) at locations PNS02-03 and PNS02-04. The reference sediment, collected from eastern Pensacola Bay, was comprised of approximately 64 percent silt-clay, 34 percent sand, and 2 percent gravel.

Of the 142 chemical constituents tested in the sediments, 56 were detected in Naval Station Pensacola turning basin sediments (39 percent). The frequency of detected constituents for each analytical fraction is provided in Table 8-1. Metals and PAHs were the most commonly detected chemical constituents in the sediment. Forty-four of the 142 tested constituents were detected in the Naval Station Pensacola reference site sediment (31 percent).

Comparisons of chemical concentrations in Naval Station Pensacola turning basin sediments to appropriate marine SQGs indicated that most of the organic contaminants are present in the sediment in concentrations that would not be expected to adversely affect aquatic organisms (Table 8-2 and 8-3). Concentrations of eleven of PAHs and four metals were found to exceed TEL values in at least one of the turning basin samples. The concentrations of two metals, copper and lead, exceeded PEL values at one location (PNS02-02).

Comparisons of TBP values calculated for the detected non-polar organic chemical constituents in the Naval Station Pensacola turning basin sediments (PAHs, PCB congeners, and chlorinated pesticides) indicated that several of these constituents have the potential to bioaccumulate to higher levels in tissues exposed to sediment from the Naval Station Pensacola turning basin than tissue exposed to sediment from the reference location. Based on an evaluation of the sediment chemistry analyses and the TBP calculations, metals, chlorinated pesticides, PCB congeners, and PAHs were targeted for analysis in tissues from the bioaccumulation studies.

8.2 SITE WATER AND ELUTRIATE TESTING

Site water chemistry indicated that few chemical constituents were detected in the site water (elutriate preparation water) from Naval Station Pensacola turning basin. Of the 145 tested constituents, eleven (8 percent) were detected at low concentrations in the site water that was used to prepare the elutriates. Overall, low concentrations of three PCB congeners and four metals (arsenic, copper, manganese, and tin) were detected in the Naval Station Pensacola turning basin site water/elutriate preparation water. None of the tested chlorinated pesticides,

organophosphorus pesticides, PAHs, SVOCs, or butyltins was detected in the site water/elutriate preparation water.

Only 20 of 145 chemical constituents (14 percent) were detected in the full strength elutriates from Naval Station Pensacola turning basin. The frequency of detected constituents for each analytical fraction is provided in Table 8-4. In the elutriates, nutrients and metals were the most frequently detected constituents. Comparisons to water quality criteria for metals indicated that a maximum 2-fold dilution of the full strength elutriate would be required to comply with the saltwater acute and chronic water quality criterion for aquatic life. A maximum 9-fold dilution would be required to comply with the acute and chronic water quality criterion for $\text{NH}_3\text{-N}$. These dilutions should be quickly achieved in the water column after placement.

Overall, results of the standard elutriate tests indicated that few inorganic and organic constituents would be expected to be released in dissolved form into the water column during open water placement. Concentrations of the few constituents that could be released would quickly dissipate in the water column to concentrations below USEPA and State of Florida water quality criteria for aquatic life.

8.3 TOXICITY TESTING

8.3.1 Water Column Bioassays

Results of the water column toxicity testing are summarized in Table 8-5. In the water column tests for *Arabacia punctulata* the test duration was extended past 48 hours in order to achieve full control development to the pluteus stage. The tests were terminated after 67 hours of exposure. The elutriates prepared from the reference sediment (PNSREF02) and the sediment from PNS02-01, PNS02-02, PNS02-05 were not acutely toxic to *A. punctulata*, as evidenced by 67-hour EC50s of >100 percent elutriate. Samples PNS02-03 and PNS02-04 were acutely toxic with 67-hour EC50s of 77.2 and 67.2 percent elutriate, respectively. The site water used to prepare the elutriates was not toxic to *A. punctulata*, with 99 percent normal development in the undiluted site water/elutriate preparation water.

Results of the water column testing with *Americamysis bahia* indicated that none of the Naval Station Pensacola elutriates were acutely toxic to *A. bahia*, with 96-hour LC50s of greater than 100 percent elutriate. The site water had 94 percent survival and was not acutely toxic to *A. bahia*. Survival in the laboratory control ranged from 92 to 100 percent all *A. bahia* toxicity tests.

The results of the water column testing with *Cyprinodon variegatus* indicated that none of the Naval Station Pensacola elutriates were acutely toxic to *C. variegatus*, with 96-hour LC50s of greater than 100 percent elutriate and a minimum of 96 percent survival in the 100 percent elutriate concentrations. The site water had 100 percent survival, and was not acutely toxic to *C. variegatus*. There was a minimum of 98 percent survival in the control toxicity tests for *C. variegatus*.

The limiting permissible concentration (LPC) for ocean placement is equivalent to 0.01 of the LC50 within a 4-hour dilution period inside the boundary of the placement site (USEPA/USACE

1991). The lowest LC50 value for the water column survival tests (67.2 percent) would require a dilution or mixing of approximately 149-fold to achieve the LPC. Modeling of the dilution using the specifications (i.e., dimensions and water column properties) of the placement site would be required to determine if the 149-dilution would be achieved within the 4-hour period inside the site boundary.

8.3.2 Whole-Sediment Bioassays

Poly → 01 FAIL

The results of the whole-sediment toxicity testing are provided in Table 8-6. Results of the *Neanthes arenaceodentata* whole sediment toxicity testing yielded 96 percent survival in the reference sediment (PNSREF02). Sediments PNS02-04 and PNS02-05 also had 96 percent survival. Samples PNS02-02 and PNS02-03 had 88 and 90 percent survival, respectively, and were not significantly ($p=0.05$) less than the reference sediment. Sample PNS02-01 had 80 percent survival which was both significantly ($p=0.05$) less than, and more than 10 percent lower than, survival in the reference sediment.

Amphipod → 04 FAIL

Results of the *Leptocheirus plumulosus* whole sediment toxicity yielded 84 percent survival in the reference sediment (PNSREF02) and 95 percent survival in the control sediment. Sediments PNS02-02, PNS02-03, and PNS02-05 had 79 to 82 percent survival, none of which were significantly ($p=0.05$) less than the reference sediment. Therefore, sediments from PNS02-02, PNS02-03, and PNS02-05 were not acutely toxic to *L. plumulosus*. Sediments PNS02-01 (64 percent survival) and PNS02-04 (49 percent survival) had significantly ($p=0.05$) lower survival than the reference sediment. Survival at PNS02-04 was also more than 20 percent lower than the reference survival.

8.4 BIOACCUMULATION STUDIES

Survival results from the bioaccumulation tests with *N. virens* (sand worm) and *M. nasuta* (blunt-nose clam) are provided in Table 8-7. After 28 days of exposure, none of the test sediments had significantly ($p=0.05$) lower survival than the reference sediment, indicating that the sediments did not adversely affect survival during the exposure period of *N. virens* or *M. nasuta*.

Based on the results of the sediment analyses, tissues samples were analyzed for metals, PAHs, PCB congeners, chlorinated pesticides, and lipids. Results of the tissue analyses for *N. virens* and *M. nasuta* are summarized by location in Tables 8-8 and 8-9, respectively. Mean lipid values ranged from 0.616 to 1.94 percent of total wet body weight for the worms and from 0.502 to 1.04 percent of total wet body weight for the clams.

In the worm tissue, three metals (arsenic, copper, and zinc) statistically exceeded the reference site tissue concentrations. None of the tested PAHs, PCB congeners or chlorinated pesticides detected in the worm tissue residues exposed to the Pensacola Naval Station turning basin sediments statistically exceeded the reference site tissue concentrations. In the clam tissue, two PAHs (fluoranthene and pyrene), one PCB congener, and the total PCB concentration detected in samples from PNS02-02 were statistically greater than concentrations detected at the reference location. None of the tested metals or chlorinated pesticides detected in the Naval Station Pensacola turning basin clam tissue statistically exceeded the reference site tissue concentrations.

Uptake ratios (UR) for the detected constituents that statistically exceeded the reference concentration in Pensacola Naval Station tissue residues were each less than 1 or slightly exceeded 1, indicating that a portion of the of the significant concentrations for the test tissues were actually lower than the concentrations in the pre-test tissue (non-exposed tissue). In such cases, it is likely that the significant exceedances represent either natural or analytical variability of concentrations within the tissue samples, rather than contaminant uptake from the sediments.

USEPA Guidance Levels exist for arsenic, cadmium, chromium, lead, and nickel. Results indicated that the tissue-residue concentrations for these constituents were statistically lower than the guidance levels in both the worm and the clam tissue residues.

8.5 STFATE MODELING AND LIMITING PERMISSIBLE CONCENTRATION COMPLIANCE

The Pensacola offshore ODMDS was identified as the location for the placement of material dredged from the Naval Station Pensacola turning basin because: 1) the Pensacola offshore ODMDS was designed to accept predominately fine grained material, 2) it is close to the project location, and 3) it has the capacity to accept material. Because the material proposed for dredging from the Naval Station Pensacola turning basin does not meet the exclusionary criteria (Part 227.13) and previous testing data were not attainable, tiered testing following protocols in *The Green Book* (USEPA/USACE 1991) and the *Region IV Regional Implementation Manual* (USACE-SAD/USEPA Region IV 1993) were conducted for samples collected from the proposed dredging area.

8.5.1 Elutriate Testing

Comparisons to water quality criteria indicated that a maximum 9-fold dilution would be required to comply with the acute and chronic water quality criterion for $\text{NH}_3\text{-N}$. Results of the STFATE modeling indicated that a dilution of approximately 208-fold within the first hour exceeds the dilution necessary to meet the acute and chronic water quality criteria for ammonia; therefore, the $\text{NH}_3\text{-N}$ concentration detected in the elutriate meets the limiting permissible concentration (LPC) for ocean placement at the Pensacola offshore Ocean Dredged Material Disposal Site (ODMDS).

Overall, results of the standard elutriate tests indicated that few inorganic and organic constituents would be expected to be released in dissolved form into the water column during open water placement. Based on the STFATE modeling, concentrations of the few constituents that could be released would quickly dissipate in the water column to concentrations below USEPA and State of Florida water quality criteria for aquatic life.

8.5.2 Water Column Toxicity

The LPC for ocean placement is equivalent to 0.01 of the EC50/LC50 within a 4-hour dilution period inside the boundary of the placement site (USEPA/USACE 1991). The lowest EC50/LC50 value for the water column survival tests (67.2 percent for *A. punctulata* for location

PNS02-04) would require a dilution or mixing of approximately 149-fold to achieve the LPC. STFATE modeling of the dilution using the specifications (i.e., dimensions and water column properties) of the placement site was conducted to determine if the 149-dilution would be achieved within the 4-hour period inside the site boundary.

STFATE modeling indicated that a 1540-fold available dilution would be achieved within 4 hours following placement, which is sufficient to satisfy 1 percent of the EC50 value (Appendix H). Therefore, the EC50 value of 67.2 percent for *A. punctulata* meets the LPC for ocean placement at the Pensacola offshore ODMDS.

8.5.3 Benthic Toxicity

Survival data for the individual stations within the Pensacola Naval Station turning basin indicated that material from station PNS02-01 and from PNS02-04 would not meet the LPC for benthic toxicity individually based on the results for *N. arenaceodentata* and *L. plumulosus*, respectively.

To determine overall compliance with the LPC for *N. arenaceodentata* and *L. plumulosus*, the survival data from each of the five sampling areas was pooled to calculate an overall mean survival value that would be representative of the material from the turning basin (as a whole) to be dredged and placed at the Pensacola ODMDS (Appendix H). For *N. arenaceodentata*, results for the pooled data (all locations combined) indicated a mean survival of 90 percent, which was not significantly lower than the reference survival (96 percent). For *L. plumulosus*, results for the pooled data (all locations combined) indicated a mean survival of 70 percent, which was not significantly lower than the reference survival (84 percent). Results of the pooled survival data (Appendix H) for *N. arenaceodentata* and *L. plumulosus* meet the LPC for benthic toxicity.

8.5.4 Benthic Bioaccumulation

Few contaminants of concern in organisms exposed to dredged material from Naval Station Pensacola turning basin statistically exceeded those of organisms exposed to reference sediment. Three metals (arsenic, copper, and zinc) had concentrations in worms that statistically exceeded the reference concentrations, however, the concentrations were nearly equivalent to concentrations in pre-test tissues. Two PAHs, one PCB congener and total PCB concentrations in clam tissue statistically exceeded the reference tissue, but the uptake ratios for each of these constituents were either less than or slightly greater than 1, indicating that concentrations for the test tissues were about the same as concentrations reported in the pre-test tissue (non-exposed tissue). Therefore, it is likely that the significant exceedances represent either natural or analytical variability of concentrations within the tissue sample, rather than contaminant uptake from the sediment. None of the tissue-residue concentrations for which USEPA Guidance Level exist exceeded the Guidance Levels. Therefore, the dredged material meets the LPC for bioaccumulation, and complies with the benthic criteria of Part 227.13 (c) (3).

TABLE 8-1. NAVAL STATION PENSACOLA TURNING BASIN BULK SEDIMENT: FREQUENCY OF DETECTED CHEMICAL CONSTITUENTS FOR TARGET ANALYTE FRACTIONS

		PNS02REF	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05	TOTAL DETECTS	SITE-WIDE PERCENT
ANALYTICAL FRACTION	# ANALYTES TESTED	FREQUENCY OF DETECTION							
GENERAL CHEMISTRY PARAMETERS	8	6	5	6	6	6	6	35	72.9
METALS	18	13	14	14	15	16	11	83	76.9
PAHs	18	14	17	18	12	0	16	77	71.3
PCB CONGENERS	26	6	12	7	0	0	1	26	16.7
CHLORINATED PESTICIDES	22	3	3	0	0	1	0	7	5.3
ORGANOPHOSPHORUS PESTICIDES	5	0	0	0	0	0	0	0	0
SVOCs	42	0	0	0	0	0	0	0	0
BUTYL TINS	3	0	0	0	0	0	0	0	0

TABLE 8-2. NAVAL STATION PENSACOLA TURNING BASIN BULK SEDIMENT: NUMBER OF DETECTED CONCENTRATIONS IN TARGET ANALYTICAL FRACTIONS THAT EXCEEDED TELs

ANALYTICAL FRACTION	PNS02REF	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05	TOTAL NUMBER OF TEL EXCEEDANCES
METALS	1	2	4	1	1	1	10
PAHs	1	5	11 ^(a)	1	0	0	18
PCB CONGENERS	0	0	0	0	0	0	0
CHLORINATED PESTICIDES	0	0	0	0	0	0	0
SVOCs	0	0	0	0	0	0	0
TOTAL TEL EXCEEDANCES	2	7	15	2	1	1	

^(a) concentrations of total PAHs (ND=0) and (ND=1/2) also exceeded TEL values but were not included in calculation

TABLE 8-3. NAVAL STATION PENSACOLA TURNING BASIN BULK SEDIMENT: NUMBER OF DETECTED CONCENTRATIONS IN TARGET ANALYTICAL FRACTIONS THAT EXCEEDED PELs

ANALYTICAL FRACTION	PNS02REF	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05	TOTAL NUMBER OF PEL EXCEEDANCES
METALS	0	1	1	0	0	0	2
PAHs	0	0	0	0	0	0	0
PCB CONGENERS	0	0	0	0	0	0	0
CHLORINATED PESTICIDES	0	0	0	0	0	0	0
SVOCs	0	0	0	0	0	0	0
TOTAL PEL EXCEEDANCES	0	1	1	0	0	0	0

TABLE 8-4. NAVAL STATION PENSACOLA TURNING BASIN SITE WATER AND ELUTRIATES: FREQUENCY OF DETECTED CHEMICAL CONSTITUENTS FOR TARGET ANALYTE FRACTIONS

ANALYTICAL FRACTION	# ANALYTES TESTED	PNS02-04-SW	PNS02REF	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05
GENERAL CHEMISTRY PARAMETERS	8	4	5	5	5	5	5	6
METALS	18	4	7	8	6	5	7	7
PAHs	18	0	0	0	1	0	0	0
PCB CONGENERS	26	3	3	1	1	1	1	1
CHLORINATED PESTICIDES	22	0	2	0	0	0	0	0
ORGANOPHOSPHORUS PESTICIDES	5	0	0	0	0	0	0	0
SVOCs	42	0	0	0	0	0	0	0
BUTYL TINS	3	0	0	0	1	1	1	1
		0	0	0	0	0	0	0

TABLE 8-5. SUMMARY OF THE RESULTS FOR WATER COLUMN TOXICITY TESTS FOR THE NAVAL STATION PENSACOLA TURNING BASIN

SAMPLE IDENTIFICATION	Purple Sea Urchin <i>Arbacia punctulata</i>			Opossum Shrimp <i>Americamysis bahia</i>			Sheepshead Minnow <i>Cyprinodon variegatus</i>		
	67-hour ^(a) EC50 (% elutriate)	Statistical Difference 100% vs. Control ^(b)	Dilution Required to Achieve 0.01 EC50	96-hour LC50 (% elutriate)	Statistical Difference 100% vs. Control ^(b)	Dilution Required to Achieve 0.01 LC50	96-hour LC50 (% elutriate)	Statistical Difference 100% vs. Control ^(b)	Dilution Required to Achieve 0.01 LC50
PNS02-01	>100	No	NA	>100	No	NA	>100	No	NA
PNS02-02	>100	No	NA	>100	No	NA	>100	No	NA
PNS02-03	77.2	Yes	130	>100	No	NA	>100	No	NA
PNS02-04	67.2	Yes	149	>100	No	NA	>100	No	NA
PNS02-05	>100	No	NA	>100	No	NA	>100	No	NA
Pensacola Bay Reference (PNSREF02)	>100	No	NA	>100	No	NA	>100	No	NA

(a) Test duration was extended past 48-hours to achieve full control development to the pluteus stage

(b) Statistical significance analyzed at P=0.05; survival (LC50) or normal development (EC50) in 100% elutriate significantly lower than the control.

NA = mixing calculation is not applicable if mean survival in 100% elutriate is not statistically lower than the mean survival in the laboratory control.

**TABLE 8-6. SUMMARY OF RESULTS FOR WHOLE SEDIMENT TOXICITY TESTS FOR THE NAVAL STATION
PENSACOLA TURNING BASIN**

SAMPLE IDENTIFICATION	Estuarine Polychaete <i>Neanthes arenaceodonta</i>			Estuarine Amphipod <i>Leptocheirus plumulosus</i>		
	10-Day Mean Survival (%)	Statistical Difference vs. Pensacola Bay Reference ^(a)	Greater than 10% difference with Reference?*	10-Day Mean Survival (%)	Statistical Difference vs. Pensacola Bay Reference ^(a)	Greater than 20% difference with Reference?*
Laboratory Control Sediment ^(b)	96	NA	-	95	NA	-
PNS02-01	80	Yes	Yes	64	Yes	No
PNS02-02	88	No	-	79	No	-
PNS02-03	90	No	-	79	No	-
PNS02-04	96	No	-	49	Yes	Yes
PNS02-05	96	No	-	82	No	-
Pensacola Bay Reference Site (PNSREF02)	96	NA	-	84	NA	-

* = Criterion applicable only if test survival is statistically lower than reference survival.

(a) Statistical significance analyzed at P=0.05; turning basin sediments statistically compared to Pensacola Bay Reference Site

(b) Control serves as indicator for test acceptability/validity

NA = not applicable; control and reference survival not statistically compared as per USEPA/USACE guidelines (1998)

**TABLE 8-7. SUMMARY OF RESULTS: BIOACCUMULATION
SURVIVAL FOR PENSACOLA NAVAL STATION TURNING BASIN
TEST SEDIMENTS**

SAMPLE IDENTIFICATION	BIOACCUMULATION TESTS	
	Sand worm <i>Nereis virens</i>	Blunt-nose clam <i>Macoma nasuta</i>
	Mean 28-day Survival (%)	Mean 28-day Survival (%)
Laboratory Control Sediment	100	99
PNS02-01	98	97
PNS02-02	100	98
PNS02-03	100	97
PNS02-04	100	93
PNS02-05	100	97
Pensacola Bay Reference Site (PNSREF02)	100	98

TABLE 8-8. PENSACOLA NAVAL STATION TURNING BASIN: NUMBER OF TESTED ANALYTES STATISTICALLY EXCEEDING REFERENCE CONCENTRATION IN *Nereis virens* TISSUE (SAND WORM)

FRACTIONS	# ANALYTES TESTED	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05	EXCEEDANCES BY FRACTION
METALS	18	1	0	1	1	1	4
PAH	18	0	0	--	--	--	0
PCB CONGENERS	26	0	0	--	--	--	0
CHLORINATED PESTICIDES	22	0	--	--	--	--	0
TOTAL EXCEEDANCES BY LOCATION	-	1	0	1	1	1	

TABLE 8-9. PENSACOLA NAVAL STATION TURNING BASIN: NUMBER OF TESTED ANALYTES STATISTICALLY EXCEEDING REFERENCE CONCENTRATION IN *Macoma nasuta* TISSUE (BLUNT-NOSE CLAM)

FRACTIONS	# ANALYTES TESTED	PNS02-01	PNS02-02	PNS02-03	PNS02-04	PNS02-05	EXCEEDANCES BY FRACTION
METALS	18	0	0	0	0	0	0
PAH	18	0	2	--	--	--	2
PCB CONGENERS	26	1	0	--	--	--	1
CHLORINATED PESTICIDES	22	0	--	--	--	--	0
EXCEEDANCES BY LOCATION	-	1	2	0	0	0	

9. REFERENCES

- American Society for Testing and Materials (ASTM). 1995. *Annual Book of ASTM Standards*. Volume 4.08. ASTM, Philadelphia, PA.
- Ankley, G.T., P.M. Cook, A.R. Carlson, D.J. Call, J.K. Swenson, H.F. Corcoran, and R.A. Hoke. 1992. Bioaccumulation of PCB from sediments by oligochaetes and fish. *Can. J. Fish. Aquat. Sci.* 49:2080-2085. (cited by USEPA/USACE 1998).
- Buchman, M.F. 1999. *NOAA Screening Quick Reference Table*, NOAA HAZMAT Report 99-1, Seattle, WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration. 12 pages.
- Clark, J.U. 1995. Guidelines for statistical treatment of less than detection limit data in dredged sediment evaluations. Technical Note EEDP-04023. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Conover, W.J. 1980. *Practical Nonparametric Statistics*. 2nd Edition. Wiley, NY.
- EA Engineering, Science, and Technology, Inc. 2002a. *Work Plan: Evaluation of Dredged Material: Naval Station Pensacola Turning Basin, Pensacola, Florida, Pensacola Harbor, Pensacola, Florida, Mobile Ship Channel, Mobil Bay, Alabama, and Sediment Evaluation for Areas Adjacent to the Arlington-Garrows Bend Channels, Mobile, Alabama, Escambia County, Florida. Final*. Prepared for USACE-Mobile District. November.
- EA Engineering, Science, and Technology, Inc. 2002b. *Field Sampling Plan: Evaluation of Dredged Material: Naval Station Pensacola Turning Basin, Pensacola, Florida, Pensacola Harbor, Pensacola, Florida, Mobile Ship Channel, Mobil Bay, Alabama, and Sediment Evaluation for Areas Adjacent to the Arlington-Garrows Bend Channels, Mobile, Alabama. Final*. Prepared for USACE-Mobile District. August.
- EA. Engineering, Science, and Technology, Inc. 2002c. *EA Ecotoxicology Laboratory Quality Assurance and Standard Operating Procedures Manual*. EA Manual ATS-102. Internal document prepared by EA's Ecotoxicology Laboratory, EA Engineering, Science, and Technology, Inc., Sparks, Maryland.
- Long, E.R. and D.D. MacDonald. 1998. Recommended uses of empirically derived sediment quality guidelines for marine and estuarine ecosystems. *Human and Ecological Risk Assessment* 4 (5): 1019-1039.
- MacDonald, D.D., R.S. Carr, F.D. Calder, E.R. Long, and C.G. Ingersoll. 1996. Development and evaluation of sediment quality guidelines for Florida coastal waters. *Ecotoxicology* 5:253-278.

- MacFarland, V.A., and J.U. Clarke. 1999. *Analysis of Uncertainty in TBP Estimation of PAH Bioaccumulation Potential in Sediments*. Dredging Research Technical Notes Collection (EEDP-04-32). U.S. Army Engineer Research and Development Center, Vicksburg, MS.
- National Oceanic and Atmospheric Administration (NOAA). 1993. *Sampling and Analytical Methods of the National Status and Trends Program: National Benthic Surveillance and Mussel Watch Projects 1984-1992. Vol 1: Overview and Summary of Methods*. NOAA Tech. Memo. NOS ORCA 71. Silver Spring, MD.
- O'Connor, T.P., K.D. Daskalakis, J.L. Hyland, J.F. Paul, and J.K. Summers. 1998. Comparisons of measured sediment toxicity with predictions based on chemical guidelines. *Environ. Toxicol. Chem.* 17:468:471.
- O'Connor, T.P., and J.F. Paul. 1999. Misfit between sediment toxicity and chemistry. *Marine Pollution Bulletin* 40:59-64.
- Pruell, R.J., N.I. Rubinstein, B.K. Taplin, J.A. LiVolsi, and R.D. Bowen. 1993. Accumulation of polychlorinated organic compounds from sediment by three benthic marine species. *Arch. Environ. Contam. Toxicol.* 24:290-297.
- Severn Trent Laboratories–Pittsburgh (STL–Pittsburgh). 2002. *Final Quality Assurance Project Plan: Physical and Chemical Analyses for Dredged Material Evaluation: Naval Station Pensacola, Pensacola, Florida, Pensacola Harbor, Pensacola, Florida; Mobile Ship Channel, Mobile Bay, Alabama, and Sediment Evaluation for Areas Adjacent to the Arlington-Garrows Bend Channel, Mobile, Alabama*. Final. Prepared for USACE–Mobile District. March.
- Sokal and Rohlf. 1981. *Biometry*. 2nd Edition. W.H. Freeman and Company, San Francisco, CA.
- U.S. Army Corps of Engineers (USACE), Waterways Experiment Station (WES). 1996. *Proposed New Guidance for Interpreting the Consequences of Bioaccumulation From Dredged Material*. Environmental Effects of Dredging Technical Notes. EEDP-01-41. August.
- U.S. Army Corps of Engineers (USACE), Waterways Experiment Station (WES). 1998. *Use of Sediment Quality Guidelines (SQGs) in Dredged Material Management*. Dredging Research Technical Note EEDP-04-29.
- U.S. Army Corps of Engineers (USACE), Waterways Experiment Station (WES). 1999. *Interpreting Bioaccumulation Data with the Environmental Residue-Effects Database*. Dredging Research Technical Note EEDP-04-30.
- U.S. Environmental Protection Agency (USEPA). 1979. *Methods for Chemical Analysis of Water and Wastes*. EPA-600/4-79-020.

- U.S. Environmental Protection Agency (USEPA) 1988. *Determination of Total Organic Carbon in Sediment (Lloyd Khan Method)*. Environmental Services Division, Monitoring Management Branch, Edison, New Jersey.
- U.S. Environmental Protection Agency (USEPA) 1991. *Draft Analytical Method for the Determination of Acid Volatile Sulfide in Sediment*. Office of Water and Office of Science and Technology. Washington D.C.
- U.S. Environmental Protection Agency (USEPA). 1997. *Test Methods for Evaluating Solid Waste. Physical/Chemical Methods*. 3rd Edition, including final update III. EPA SW-846, Washington D.C.
- U.S. Environmental Protection Agency (USEPA). 2001. *Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual*. Office of Water. Washington D.C.
- U.S. Environmental Protection Agency (USEPA). 2002. *National Recommended Water Quality Criteria*. EPA-822-R-02-047.
- U.S. Environmental Protection Agency (USEPA) / U.S. Army Corp of Engineers (USACE). 1991. *Evaluation of Dredged Material Proposed for Ocean Disposal*. EPA-503/8-91/001. "The Green Book."
- U.S. Environmental Protection Agency (USEPA) / U.S. Army Corp of Engineers (USACE). 1995. *QA/QC Guidance for Sampling and Analysis of Sediment, Water, and Tissue for Dredged Material Evaluations*. EPA-B-95-001.
- U.S. Environmental Protection Agency (USEPA) / U.S. Army Corp of Engineers (USACE). 1998. *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Inland Testing Manual (ITM)*. EPA-823-B-98-004.
- U.S. Environmental Protection Agency, Region IV (USEPA, Region IV) / U.S. Army Corp of Engineers, South Atlantic Division (USACE-SAD). 1993. *Regional Implementation Manual (RIM). Requirements and Procedures for Evaluation of the Ocean Disposal of Dredged Material in Southeastern Atlantic and Gulf Coastal Waters*. May.
- U.S. Food and Drug Administration (USFDA), Center for Food Safety and Applied Nutrition. 1998. *Fish and Fishery Products Hazards and Control Guide*. Washington, D.C.
- Wenning, R.J. and C.G. Ingersoll. 2002. *Summary of the SETAC Pellston Workshop on Use of Sediment Quality Guidelines and Related Tools for the Assessment of Contaminated Sediments*; 17-22 August 2002. Fairmount, Montana, USA. Society of Toxicology and Chemistry (SETAC). Pensacola, FL, USA.